TECHNOLOGY DEPT.

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Journal

of

THE ROYAL AERONAUTICAL SOCIETY

APRIL 1958

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News of TACA Viscount Experience

Ricardo H. Kriete, President of TACA International Airlines, announced recently in San Salvador that in the first six weeks of operation over its routes the Vickers Viscount has shown encouraging traffic trends.

'On certain routes the load factor has been as high as 86%. The load factor over all routes on which the company operates the Viscount schedules has been 73%. Passenger reaction in our area has been most enthusiastic for the new jet-prop aircraft', said Mr. Kriete.

Passenger-appeal is often considered intangible. In the Vickers Viscount it is a conscious feature of design, based on experience. Peace of mind as well as physical comfort have been translated into practical terms, and independent studies have shown that Viscount passengers experience less fatigue than other air travellers. Built-in ease of maintenance speeds turn-round and avoids the irritation of airport delays.

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For convenience, and in order to make possible the revision of individual Data Sheets, each sheet is loose leaf. Most sheets consist of a graph or table on one side with a complete list of notation, notes on method of use, details of the derivation and a worked numerical example on the other side. Some are entirely self-contained while others are used as part of a series giving a complete analytical method; such a series also contains individual sheets devoted entirely to explanatory matter and worked examples.

To ensure that Data Sheets are authoritative, they are prepared by the Society's permanent Technical Staff working with the guidance of Committees composed of the leading specialists in Industry, Research Establishments and the Universities, together with special advisers for each subject. That the Data Sheets achieve a high degree of usefulness and authority is witnessed by their wide circulation and use in the Aircraft Industry, Research Establishments and Universities both in the United Kingdom and in more than 30 countries abroad. Most aircraft companies, for example, have several copies of each series.

As new data becomes available, it is used to check existing sheets and to revise them if necessary; alternatively it is used to produce entirely new sheets. At regular intervals copies of these revised or new sheets are distributed to all holders of Data Sheet Volumes, an appropriate charge being made for this service.

Volumes of Data Sheets may be obtained by both members and non-members of the Royal Aeronautical Society and there are special reduced rates for members of the Society and certain other bodies. An illustrated brochure is available on application to the Secretary.

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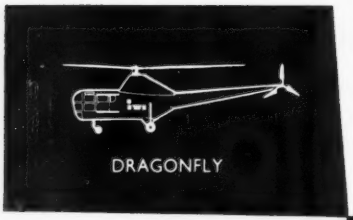

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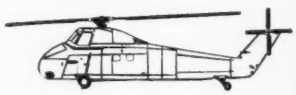

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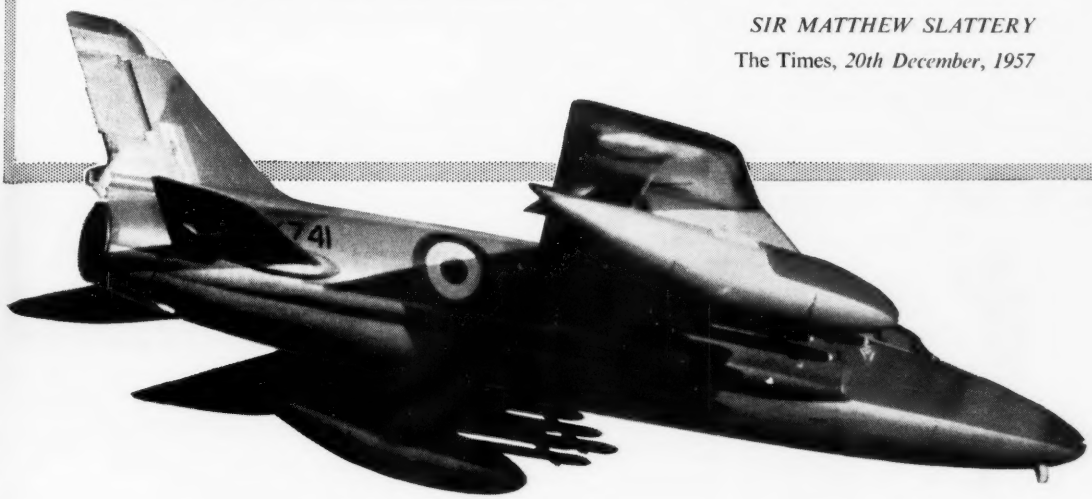
SIR MATTHEW SLATTERY
The Times, *20th December, 1957*



The guided missile is indeed the 'ultimate' weapon—the *last* weapon to be used or considered. That is why considered strategic thinking supports the use of more conventional weapons in the first instance; but they must be swift in execution to fulfil their object—the rapid resolution of local conflicts which could so easily spread and bring the ultimate weapon into operation. An Air Force that is flexible as well as effective is the best means of fulfilling that object.

The Folland GNAT, as the fighter component of such an Air Force, is a sound economic proposition. For it has reversed the trend to greater size, complexity and cost in more conventional fighter design. Compared with any conventional fighter, it has better manoeuvrability, a greater operating height and the most advanced armament and equipment; its simplicity makes little demand on skilled maintenance. As a strategic or tactical fighter of the first rank, the GNAT is the right aircraft, for the right job, at the right time.

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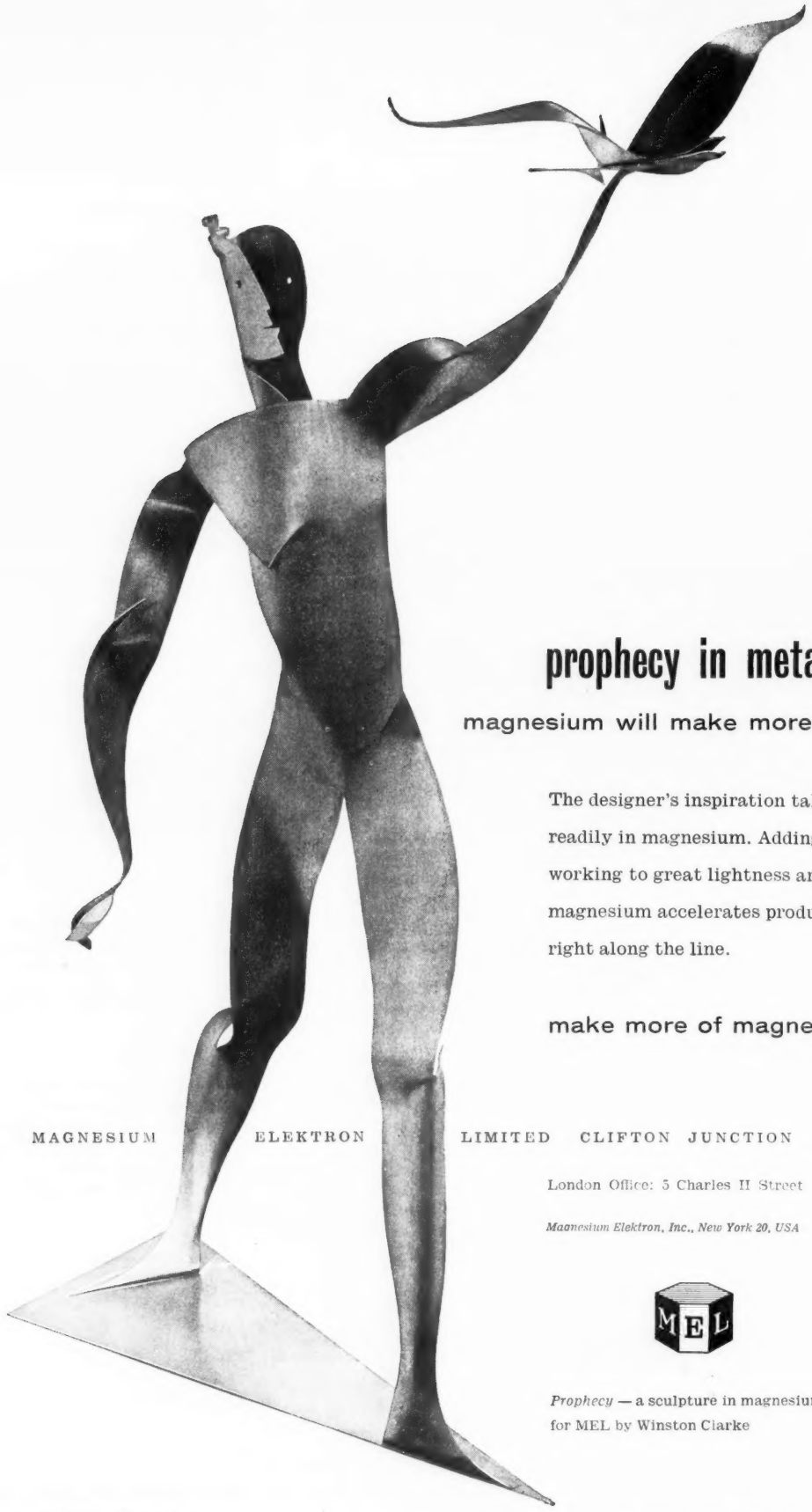

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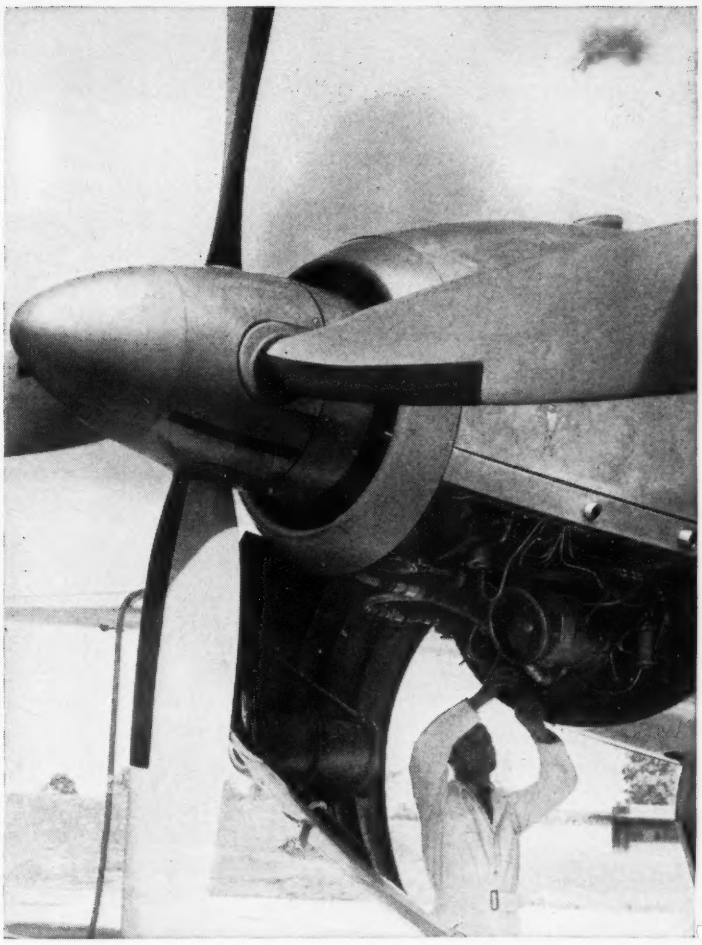

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The Eland is designed for economy. A Convair with piston engines will carry a full payload 250 miles, but the same aircraft, after conversion to Eland engines, is able to extend its range to 970 miles and increase its speed by 55 m.p.h. The extra 2,000 h.p. that is developed by the Elands enables the same aircraft to carry its full payload under operating conditions of extreme temperatures and altitudes. This economy and flexibility can be expressed in substantially lower operating costs.

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Passengers need no technical knowledge of aircraft to form stubborn preferences. Once they have experienced (or been told about) the smoothness and quietness of turbo prop flight, they will avoid travelling by piston engined aircraft whenever possible. In addition, the greater simplicity and reliability of the turbo prop engine are factors that weigh heavily with the passenger and influence his choice of airline.

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While the final decision depends on a number of variables—such as the life of the aircraft, its book value and its revenue earning power—it is almost always sounder economics to convert an existing piston engined machine than to buy a new airliner. An Eland conversion can be carried out for less than a third of the cost of a new aircraft with the certainty that this expenditure will be quickly recovered by the increased earning power.

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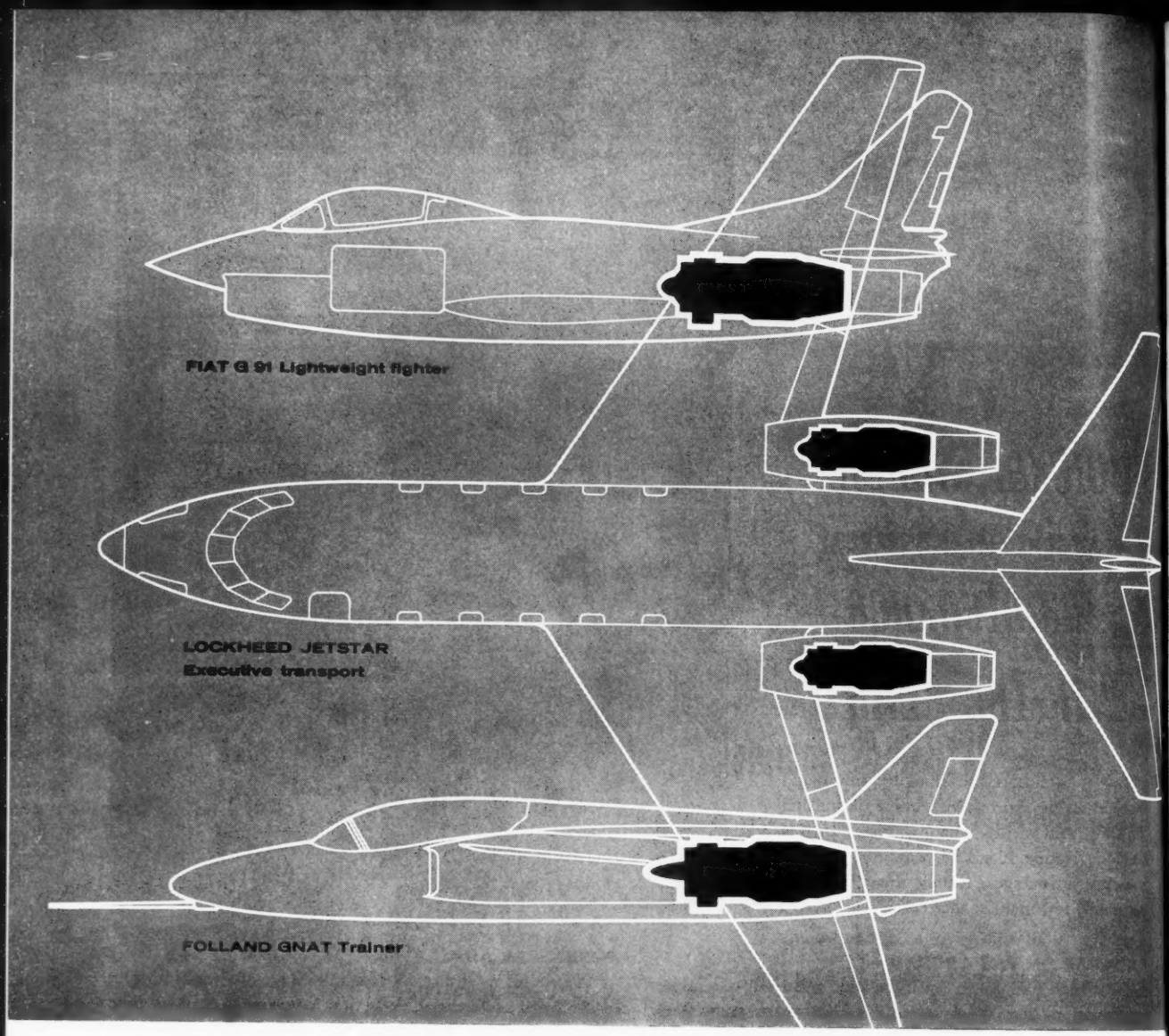

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Lockheed CL—329 Jetstar *	US

Trainers (Derated Orpheus)

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Folland Gnat Trainer	UK
North American Model 249 (alternative engine)*	US
Fiat G 91T	ITALY

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Orpheus development continues. The latest version, the B Or 12, has a still higher power/weight ratio, giving 6,810 lb thrust dry, over 8,000 lb with Bristol simplified reheat.

*Production versions of the Jetstar and North American Model 249 are being offered with Curtiss-Wright TJ 37 engines. The TJ 37 is a derivative of the Orpheus, jointly developed by Bristol and Curtiss-Wright.

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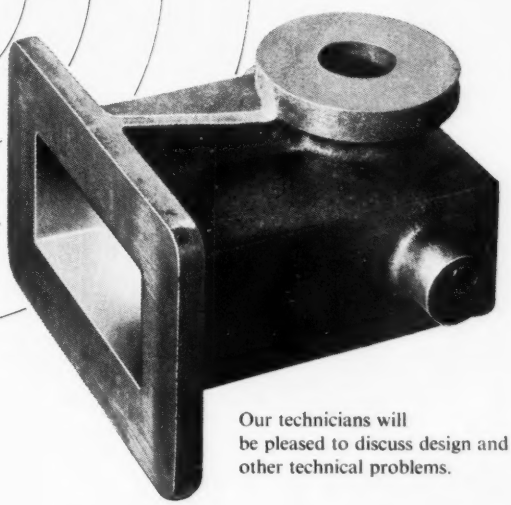

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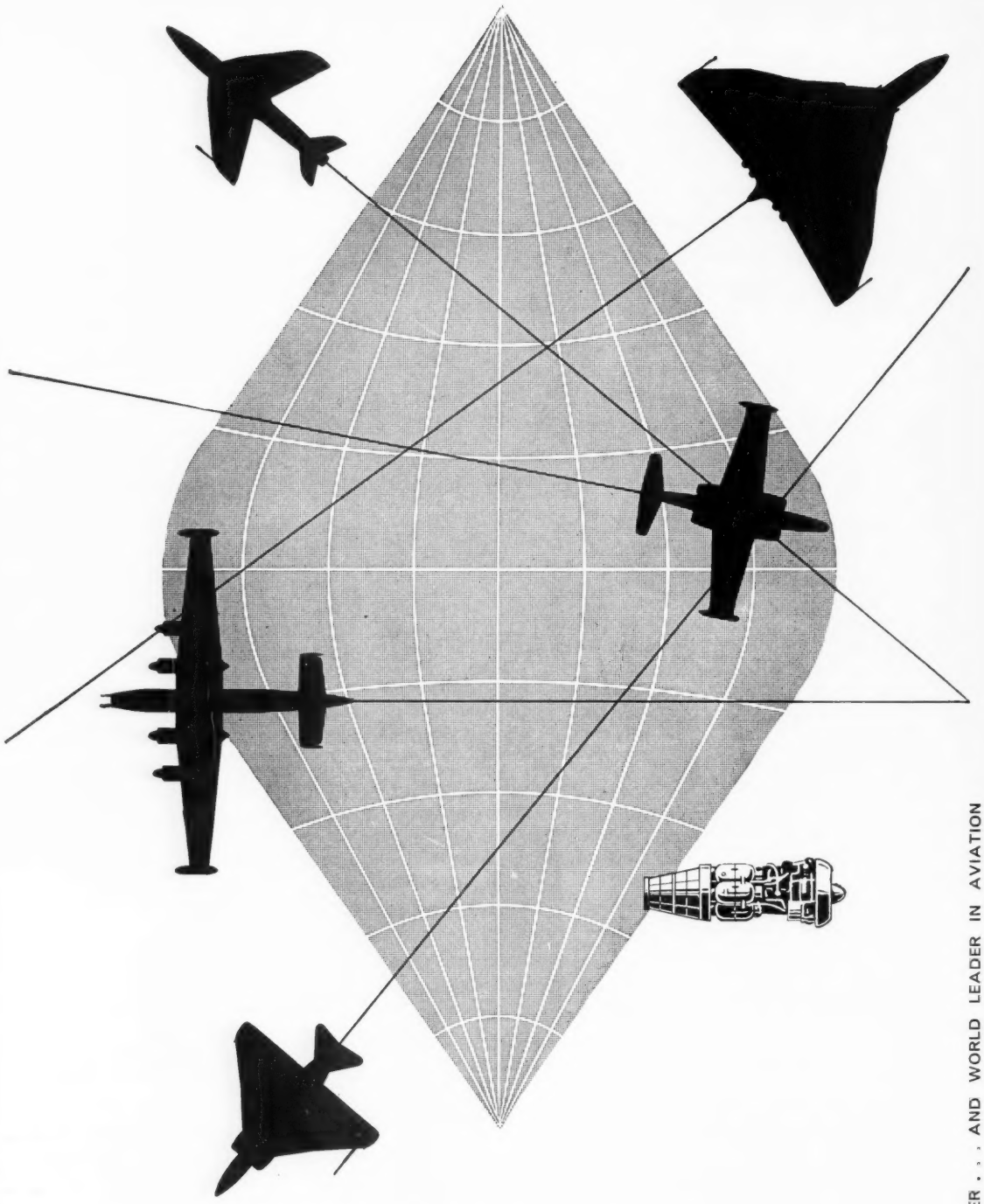

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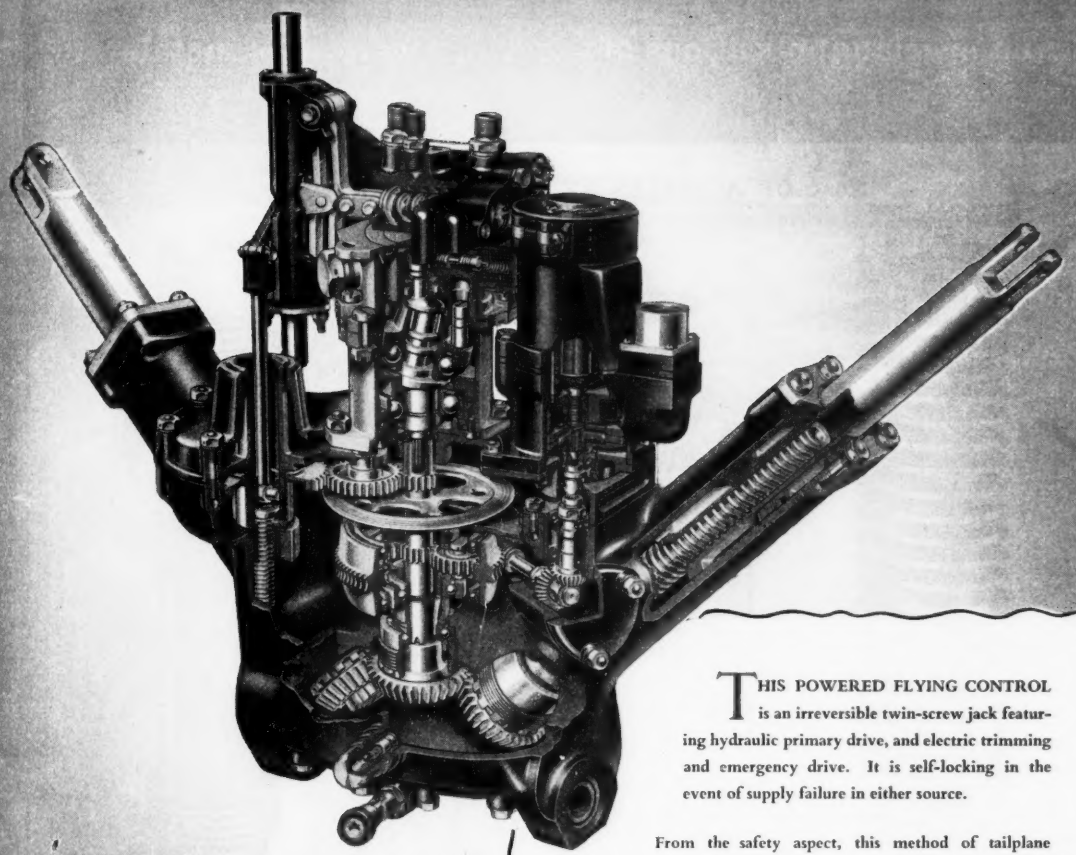

THIS POWERED FLYING CONTROL is an irreversible twin-screw jack featuring hydraulic primary drive, and electric trimming and emergency drive. It is self-locking in the event of supply failure in either source.

From the safety aspect, this method of tailplane operation from separate sources is eminently suitable for a single-engined aeroplane where duplication of hydraulic supply is difficult to arrange.

In its present installation the unit actuates the moving tailplane hydraulically, coincident with mechanical elevator operation in a set angular displacement ratio. The electric drive is used for trimming, and being independent of the mechanical linkage, permits longitudinal control by the elevator in the event of hydraulic failure.

The unit is one of many piston and screw jack type controls manufactured by

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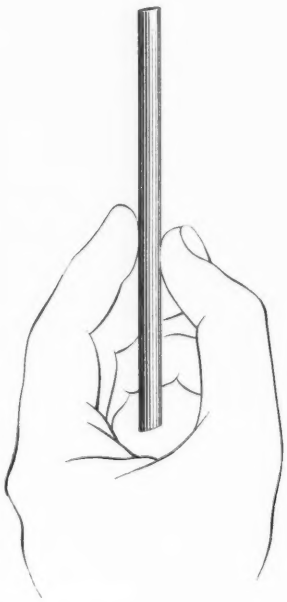
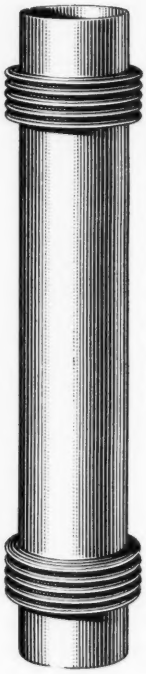
Copper electrode with two holes ·022″ i/d. The dimensions are ·225″ major axis x ·035″ minor axis.





Push rod cover tube for use in internal combustion engines. This tube is made from thin wall tubing ·750″ o/d x ·007/·008″ thick x 6″ long, convoluted at each end.

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President: Dr. A. E. RUSSELL, C.B.E., F.R.Ae.S.
Chairman: R. N. WESTAWAY.
Hon. Secretary: G. WANSBROUGH-WHITE, A.R.Ae.S., Bristol Aircraft Ltd., Filton, Bristol.

BROUGH
President: N. E. ROWE, C.B.E., F.R.Ae.S.
Chairman: M. G. K. BYRNE, A.F.R.Ae.S.
Hon. Secretary: A. D. HOWARTH, A.R.Ae.S., Blackburn & General Aircraft Ltd., Brough.

CAMBRIDGE
President: Prof. W. A. MAIR, F.R.Ae.S.
Chairman: C. F. C. SNEESBY, A.F.R.Ae.S.
Hon. Secretary: R. C. GODWIN, A.F.R.Ae.S., Marshalls Flying School, Newmarket Rd., Cambridge.

CHESTER
President: J. C. CORBY, O.B.E.
Chairman: J. G. SHARP, A.F.R.Ae.S.
Hon. Secretary: B. V. POULSTON, Thornton Research Centre, P.O. Box 1, Chester.

CHRISTCHURCH
President: W. A. TAMBLIN, F.R.Ae.S.
Chairman: G. B. EVANS.
Hon. Secretary: H. E. VINCENT, A.F.R.Ae.S., de Havilland Aircraft Co. Ltd., Airspeed Div., Christchurch Aerodrome, Hants.

COVENTRY
President: H. M. WOODHAMS, C.B.E. F.R.Ae.S.
Chairman: W. J. PETERS.
Hon. Secretary: C. T. SCULTHORPE, A.F.R.Ae.S., Sir W. G. Armstrong Whitworth Aircraft Ltd., Whitley, Coventry.

DERBY
President: J. D. PEARSON, F.R.Ae.S.,
Chairman: A. A. RUBBRA, F.R.Ae.S.
Hon. Secretary: W. R. BENDALL, A.F.R.Ae.S., Rolls-Royce Ltd.

GLASGOW
President: Professor W. J. DUNCAN, C.B.E., F.R.Ae.S.
Chairman: Dr. A. W. BABISTER, A.F.R.Ae.S.
Hon. Secretary: W. N. ALCOCK, Civil Engineer in Chief Department, Admiralty, Dalnottar House, Old Kilpatrick, Glasgow.

GLOUCESTER AND CHELTENHAM
President: R. H. BOUND, F.R.Ae.S.
Chairman: J. F. CUSS, A.F.R.Ae.S.
Hon. Secretary: J. G. RUSSELL, A.F.R.Ae.S., Rotol Ltd., Gloucester.

HALTON
President: Air Vice-Marshal G. SILYN ROBERTS, C.B.E., A.F.C., F.R.Ae.S.
Chairman: Gp. Capt. A. K. HUNTER, O.B.E., A.F.R.Ae.S.
Hon. Secretary: Flt. Lt. J. BEATTIE, A.R.Ae.S., Instrument Fitter Flight, Technical Wing, R.A.F. Halton.

HATFIELD
President: Sir GEOFFREY DE HAVILLAND,, C.B.E., A.F.C. Hon. F.R.Ae.S.
Chairman: R. C. GRINTER, A.F.R.Ae.S.
Hon. Secretary: J. A. KIRK, A.F.R.Ae.S., de Havilland Aircraft Co. Ltd., Hatfield, Herts.

HENLOW
President: L. H. G. STERNE, F.R.Ae.S.
Chairman: W. Cdr. I. D. H. GIBBINS, O.B.E., A.F.R.Ae.S.
Hon. Secretary: Flt. Lt. A. H. CRAVEN, A.F.R.Ae.S., R.A.F. Technical College Mess, Henlow, Beds.

ISLE OF WIGHT
President: Sir ARTHUR GOUGE, Hon. F.R.Ae.S.
Chairman: W. BROWNING, F.R.Ae.S.
Hon. Secretary: L. W. ROSENTHAL, A.F.R.Ae.S., Saunders-Roe Ltd., E. Cowes, Isle of Wight.

LEICESTER
Chairman: K. B. AYERS, A.F.R.Ae.S.
Hon. Secretary: M. G. RUSSELL, A.R.Ae.S., Design Office, Auster Aircraft, Rearsby, Leics.

LONDON AIRPORT
President: G. W. HALL, F.R.Ae.S.
Chairman: B. S. SHENSTONE, F.R.Ae.S.
Hon. Secretary: N. BROWN, A.R.Ae.S., c/o B.O.A.C. H.Q., London Airport, Middx.

LUTON
President: A. T. SLATOR.
Chairman: H. E. CURTISS.
Hon. Secretary: L. A. WILLOTT, A.F.R.Ae.S., Hunting Aircraft Ltd., Luton Airport.

MANCHESTER
President: Sir ROY H. DOBSON, C.B.E., J.P., Hon.F.R.Ae.S.
Chairman: C. E. FIELDING, O.B.E., F.R.Ae.S.
Hon. Secretary: J. A. E. WATERFALL, 56 Manor Avenue, Ashton-on-Mersey, Cheshire.

MERTHYR TYDFIL
President: CHARLES MCGIBBON.
Chairman: J. INGRAM.
Hon. Secretary: J. MCLAUGHLIN, D.S.O., D.F.C., Teddington Controls Ltd., Cefn Coed, nr. Merthyr Tydfil, South Wales.

PRESTON
President: Sir GEORGE H. NELSON.
Chairman: E. LOVELESS, A.F.R.Ae.S.
Hon. Secretary: J. H. GROUT, Grad.R.Ae.S., Aircraft Division, English Electric Co. Ltd., Warton Aerodrome, nr. Preston.

READING
President: Sir FREDERICK HANDLEY PAGE, C.B.E., Hon.F.R.Ae.S.
Chairman: R. J. FENNER, A.F.R.Ae.S.
Hon. Secretary: E. L. PEARSON, A.R.Ae.S., Handley Page (Reading) Ltd., The Aerodrome, Woodley, Reading.

SOUTHAMPTON
Chairman: D. B. SMITH, O.B.E., A.F.R.Ae.S.
Hon. Secretary: J. W. WARRISS, A.F.R.Ae.S., Air Service Training Ltd., Hamble, Hants.

SOUTHEND
President: B. F. COLLINS, A.R.Ae.S.
Chairman: S. J. SMYTH, A.F.R.Ae.S.
Hon. Secretary: J. L. MORT, A.F.R.Ae.S., c/o Aviation Traders (Eng.) Ltd., Southend Airport, Essex.

SWINDON
Chairman: W. GILLESPIE, A.F.R.Ae.S.
Hon. Secretary: J. ROSE, A.F.R.Ae.S., Vickers-Armstrongs (Aircraft) Ltd., Supermarine Works, South Marston, Swindon.

WEYBRIDGE
President: SIR GEORGE EDWARDS, C.B.E., F.R.Ae.S.
Chairman: H. H. GARDNER, F.R.Ae.S.
Hon. Secretary: E. G. BARBER, A.R.Ae.S., Vickers - Armstrongs (Aircraft) Ltd., Weybridge.

YEOVIL
President: E. C. WHEELDON.
Chairmen: D. L. HOLLIS-WILLIAMS, F.R.Ae.S., and Dr. E. W. STILL, F.R.Ae.S.
Hon. Secretary: L. A. LANSDOWN, A.F.R.Ae.S., Westland Aircraft Ltd., Yeovil.

NOTICES

Annual General Meeting—8th May 1958

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, will be held on Thursday 8th May at 5.30 p.m. in the Offices of the Society, 4 Hamilton Place, London, W.1.

AGENDA

1. To read the Notice convening the meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheet and Income and Expenditure Accounts of the Royal Aeronautical Society and Aeronautical Trusts Limited for the year ended 31st December 1957.
3. To receive the names of those elected to Council for the years 1958-1961.
4. To announce the names of Fellows elected by the Council in accordance with By-Law 4.
5. To elect the Auditors for the year 1958.
6. Any other business.

By Order of the Council,
A. M. BALLANTYNE,
Secretary.

NOTE: In accordance with the By-Laws any member whose subscription has not been paid before the first day of April is not entitled to vote.

Light refreshments will be served after the meeting.

School Holidays in France

Following the arrangements made in 1956 and 1957 concerning School Holidays in France, the Society has again received the names of children of Members of the Association Française des Ingénieurs et Téchniciens de L'Aéronautique in Paris who would like to exchange holidays with children in Britain of a similar age. Full particulars will be sent on application to the Secretary of the Society.

Prizes Awarded

The *Baden-Powell Memorial Prize* for the best candidate in the December 1957 Associate Fellowship Examinations has been awarded to Mr. R. E. Taylor of Luton, Beds.

The *Elliott Memorial Prize* for the best candidate in General Studies Examination at Halton was to be presented to Corporal Apprentice R. J. Soppitt at the Graduation Prizegiving on 2nd April 1958.

Acknowledgments

The Council wishes to thank Mr. H. O. Short (*Honorary Fellow*) for presenting a leather bound photostat copy of "Les Voyageurs Aeriens ou relations des courses faites dans les airs par M. le Major d'Arlande accompagné de M. Pilatre du Rogier le 22nd Novembre 1783" to the library. It is thought that the original, in Mr. Short's possession, is unique.

The Council also wishes to thank Mr. A. E. Berriman (*Fellow*) for the gift of lantern slides, "A System for Building Airframe Parts and Units" (Second World War), "An Analysis of the test records of Petrol Engines" (1916), a typescript of a visit to France in 1915, and aeroplane and bird silhouettes.

Easter Holidays

The Library and Offices will be closed from Thursday afternoon 3rd April until 9 a.m. on Tuesday 8th April 1958.

News of Members

F. W. Brightwell (*Associate*), formerly a Technical Author with de Havilland Aircraft Co. Ltd., is now a Technical Author with the Project and Development Branch, Engineering Department, B.E.A., London Airport.

V. Cadambe (*Associate Fellow*), formerly of the National Physical Laboratory of India, will be joining the Council of Scientific and Industrial Research as Director, Central Mechanical Engineering Research Laboratory, New Delhi.

A. D. S. Carter (*Associate Fellow*), formerly at the N.G.T.E., Farnborough, is now Professor of Mechanical Engineering at the Royal Military College of Science, Shrivenham.

N. R. Dobson (*Graduate*), formerly with the de Havilland Aircraft Co. Ltd. at Hatfield, is now in the Aerodynamics Department of Canadair Ltd., Montreal.

Lieut. D. A. Doidge (*Associate Fellow*) has been appointed for a course with the Royal Air Force, R.A.F. Technical College, Henlow.

Group Captain E. A. Harrop (*Associate Fellow*), formerly at H.Q. Fontainebleau, has been posted to Command Aeronautical Inspection Officer at H.Q. Maintenance Command, Andover.

Lieut. Cdr. F. E. Heenan (*Associate Fellow*), formerly at Manadon, Plymouth, has been appointed Officer in Charge No. 2 Fleet Work Study and Command Work Study Officer to Commander in Chief, Mediterranean.

C. P. Homes (*Associate*), formerly with Prestressed Concrete Products Ltd., has been appointed Metallurgist with the Rhodesia Chrome Mines Ltd.

Dr. J. Houghton (*Associate Fellow*), formerly Senior Lecturer in Aeronautical Engineering at Coventry Technical College, has been appointed Head of the Department of Mechanical Engineering at Brunel College of Technology, Acton.

J. W. King (*Associate*), formerly of Rediweld Ltd., is now Managing Director of Plastic Filters Ltd., Horsham.

J. E. Lauderdale (*Associate Fellow*), formerly with the de Havilland Aircraft Co. Ltd. at Hatfield, is now a Design Engineer with Lockheed Aircraft Corporation, Missile Systems Division, California.

Squadron Leader R. W. G. Ranner (*Associate Fellow*), formerly Senior Armament Officer, Waddington, has been posted to A.ARM 9 Duties, Ministry of Supply, London.

G. Selwood (*Associate Fellow*), formerly Chief Designer (Hydraulics), Fairey Aviation Co. Ltd., has joined Wilmot Breeden Ltd., Somerset, as Chief Engineer.

E. V. Starr (*Associate Fellow*), formerly in the R.T.O. office at Bristol Aircraft Ltd., Filton, has been transferred as Resident Technical Officer with the Company's Helicopter Division, Weston-super-Mare.

R. S. H. Toms (*Associate Fellow*), formerly Chief Tunnel Engineer at Bristol Aircraft Ltd., is now Research Associate at the Engineering Center of the University of Southern California.

G. D. Turner (*Graduate*), formerly at Aviation and Engineering Products Ltd., is now employed as a Senior Draughtsman with Fairey Aviation Co. Ltd., Hayes.

First International Congress of the Aeronautical Sciences—Madrid, 8-13th September

For the past 18 months the Society has been co-operating with the Institute of the Aeronautical Sciences and other organisations in plans for an International Council of the Aeronautical Sciences (I.C.A.S.). A provisional organisation has been formed with Dr. Theodore von Kármán as President of the Council and M. Maurice Roy (O.N.E.R.A.) as Chairman of the Executive Committee. The Institute of the Aeronautical Sciences, New York, has been designated as the permanent Secretariat of the International Council.

Plans are now being made for the First International Congress of the Aeronautical Sciences to be held in Madrid from 8th-13th September 1958. Eighteen countries with organised technical Societies are expected to participate.

Approximately forty papers have been selected for presentation at the First Congress in Madrid and the tentative programme is as follows:—

Monday 8th September—*Opening Session*

Daniel and Florence Guggenheim International Memorial Lecture — Th. von Kármán

Juan de la Cierva Lecture — Ing. Pedro Blanco

Tuesday 9th September—*General Session*

Aerodynamic Design for Supersonic Speeds — R. T. Jones (U.S.)

Telecommand and Navigation — W. H. Stephens (U.K.)

Propulsion Supersonics — M. Roy (France)

Special Session—Hypersonic Flow

Newtonian Flow Theory in Hypersonic Aerodynamics — W. D. Hayes (U.S.)

Dynamics of a Dissociating Gas — M. J. Lighthill (U.K.)

Special Session—Structures and Aeroelasticity

Papers by A. van der Neut (Holland); L. Broglio (Italy); R. Mazet (France); and Marten T. Landahl (Sweden)

Wednesday 10th September—*Special Session—Heat Transfer and Heat Barrier*

Mass Transfer Cooling, A Means to Protect High Speed Aircraft — E. R. G. Eckert (U.S.)

The Heat Barrier and its Influence on Hypersonic Aerodynamics — R. J. Monaghan (U.K.)

Non-Adiabatic Flow of a Gas in a Rotating Duct — Manuel de Sendasorta (Spain)

Two Papers on Heat Transfer by R. Siestrunck and J. J. Bernard (France); and E. Schmidt (Germany)

Special Session—Jet Engines and Noise

Jet Engines and Noise papers by F. B. Greatrex (U.K.); H. S. Ribner, K. K. Neely and B. Etkin (Canada); William Littlewood (U.S.); and H. Le Boiteux (France)

Special Session—Navigation and Guidance

Some Considerations of Safety in Instrument Flight Control — A. M. A. Majendie (U.K.)

On Dynamically Caused Drift Effects of Gyro-Systems — K. Magnus (Germany)

Inertial Navigation — C. S. Draper (U.S.)

Special Session—Boundary Layer Control

Boundary Layer Control Papers by H. Schlichting (Germany); G. V. Lachmann (U.K.); and M. P. Carriere, P. Poisson-Quinton and E. A. Eichelbrenner (France)

Thursday 11th September—*General Session*

Aeroelastic Problems of Aircraft Construction — H. G. Kussner (Germany)

A Review of Some Recent Developments in Hypersonic Flow — A. Ferri (U.S.)

Friday 12th September—*Special Session—VTOL-STOL*

VTOL and STOL Aeroplanes Papers by J. P. Campbell (U.S.); D. Keith-Lucas (U.K.); and M. Eggers (France)

Special Session—Heat Resistant Materials

Materials and Structures for Finite Lifetime — N. J. Hoff (U.S.)

Problems in Heat Resistant Materials for High Speed Flight and Propulsion — Pol Duwez (U.S.)

Special Session—Human Engineering

Papers by D. G. Simons (U.S.); G. Melville Jones (U.K.); and M. E. Evrard (Belgium)

Special Session—Telecommand and Telemetering

Transmission of Data by Radio from the U.S. Satellites — J. T. Mengel (U.S.)

Saturday 13th September—*General Session*

Propulsion Methods in Astronautics — W. Bollay (U.S.)

Members of the Society wishing to attend the Congress should apply to the Secretary, Dr. A. M. Ballantyne, so that they may be sent the application forms for delegates and for Hotel Reservations.

DIARY

LONDON

10th April

Main Lecture.—Guided Weapons and Aeronautics. Dr. R. Cockburn. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

15th April.

Section Lecture.—The Problems of Vertical Take-Off. Dr. C. T. Hewson. Library, 4 Hamilton Place, W.1. 7 p.m.

15th May

The Forty-Sixth Wilbur Wright Memorial Lecture.—Automatic Flight—The British Story. Dr. G. W. H. Gardner. Institution of Mechanical Engineers, Birdcage Walk, S. W. 1. 6 p.m. (Tea at 5.30 p.m.)

GRADUATES' AND STUDENTS' SECTION

18th April

The Role of the Independent Airlines in British Air Transport Development. T. W. Morton. Library, 4 Hamilton Place, W.1. 7.30 p.m.

5th May

Future Trends in Naval Air Operations. Captain O. M. Bailey. Library, 4 Hamilton Place, W.1. 7.30 p.m.

BRANCHES

10th April

Cheltenham.—Annual General Meeting and Film Show. St. Mary's College, Cheltenham. 7.30 p.m.

Yeovil.—Annual General Meeting and Film Show. Park School, Park Road. 7.30 p.m.

11th April

Hatfield.—Annual Dinner.

14th April

Halton.—Aircraft Photography. John Yoxall. Branch Hut, R.A.F. Halton. 6.45 p.m.

16th April

Brough.—Annual General Meeting. Lecture Room, Flying Club, Brough. 5.10 p.m.

Christchurch.—Joint Meeting with the Institution of Mechanical Engineers. Lecture by Dr. G. W. H. Gardner. Town Hall. 7.30 p.m.

London Airport.—Titanium. H. W. Shaw. Apprentice Lecture Room, Fairey Aviation Co. Ltd., Hayes. 6 p.m.

Preston.—Annual General Meeting and Film Show. R.A.F. Association, Preston. 7.30 p.m.

18th April

Birmingham.—Reduxed Aircraft Structures. Engineering Centre, Birmingham. 7.30 p.m.

21st April

Halton.—Film Night and Committee Meeting. Branch Hut, R.A.F. Halton. 6.45 p.m.

23rd April

Christchurch.—Annual General Meeting and Film Show. Kings Arms Hotel. 7.30 p.m.

Hatfield.—Discussion Evening. de Havilland Restaurant. 6.15 p.m.

Leicester.—Annual General Meeting and Film Show. Lecture Theatre, Loughborough College. 6.45 p.m.

30th April

Reading.—Annual General Meeting and Film Show. Upper Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

Weybridge.—Annual General Meeting. Apprentice Training School. Weybridge. 6 p.m.

1st May
Glasgow.—Small Gas Turbines. P. J. Johnson. Room 24, College of Science and Technology, Duke Street. 7.15 p.m.

6th May
Luton.—Analogue and Digital Computers. Member of Staff of Elliott Bros., Boreham Wood. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

8th May
Cambridge.—Aircraft Accidents. E. L. Ripley. No. 1 Lecture Theatre, Cambridge University Engineering Laboratories. 8.15 p.m.

12th May
Halton.—The Domain of the Helicopter. Raoul Hafner. Branch Hut, R.A.F. Halton. 6.45 p.m.

14th May
Chester.—Annual General Meeting and Film Show. Lecture Theatre, Grosvenor Museum. 7.30 p.m.

16th May
Birmingham.—Annual General Meeting. Engineering Centre. 7.30 p.m.

21st May
Hatfield.—Annual General Meeting. de Havilland Restaurant, Hatfield. 6.15 p.m.

Associate Fellowship Examination

The following Candidates were successful in the Associate Fellowship Examinations held in December 1957:—

Part I—London

Flt. Lieut. P. H. Alley, Mechanics (Distinction), Thermodynamics (Distinction), Theory of Machines; Flt. Cadet G. D. Andrews, Aerodynamics, Thermodynamics.

Flt. Cadet I. Bentley, Aerodynamics, Thermodynamics.

D. M. Devenish, Pure Mathematics, Mechanics (Distinction), Physics, Strength of Aircraft Materials and Theory of Structures (Distinction), Theory of Machines.

Flt. Cadet R. Humphrey, Aerodynamics.

J. Kime, Mechanics, Thermodynamics.

A. Omidiji, Pure Mathematics, Mechanics, Physics, Strength of Aircraft Materials and Theory of Structures, Theory of Machines.

R. V. Percival, Aerodynamics.

Flt. Cadet B. R. Rogers, Aerodynamics, Thermodynamics.

J. E. G. Townsend, Aerodynamics.

Part II—London

K. F. Burrett, Paper 11. Theory of Structures A, Paper 13. Theory of Structures C.

A. H. Comber, Paper 11. Theory of Structures A, Paper 13. Theory of Structures C.

J. Elliott, Paper 11. Theory of Structures A, Paper 13. Theory of Structures C; W. J. Everett, Paper 11. Theory of Structures A, Paper 12. Theory of Structures B, Paper 16. Thermodynamics and Theory of Machines.

N. D. Holdsworth, Paper 16. Thermodynamics and Theory of Machines.

P. G. King, Paper 11. Theory of Structures A, Paper 12. Theory of Structures B, Paper 13. Theory of Structures C.

J. R. Stoker, Paper 11. Theory of Structures A, Paper 12. Theory of Structures B, Paper 13. Theory of Structures C.

R. E. Taylor, Paper 11. Theory of Structures A, Paper 12. Theory of Structures B, Paper 13. Theory of Structures C. (Awarded the Baden-Powell Prize.)

Part II—Outside London

T. Mahood (Belfast), Paper 12. Theory of Structures B.

Part I—Abroad

J. W. Duly (Johannesburg), Physics.

J. Sen (Calcutta), Pure Mathematics, Mechanics, Physics, Strength of Aircraft Materials and Theory of Structures; M. N. Sundaresan (Mysore), Strength of Aircraft Materials and Theory of Structures (Distinction), Thermodynamics.

Part II—Abroad

K. L. Arora (Hyderabad), Paper 16. Thermodynamics and Theory of Machines, Paper 17. General Design, Piston and Turbine Engines, Paper 18. Piston and Turbine Engines (Distinction).

F. Minhas (Lahore), Paper 10, Aerodynamics C.

M. V. Narasimhan (Mysore), Paper 16. Thermodynamics and Theory of Machines.

M. K. Ramamurthy (Hyderabad), Paper 16. Thermodynamics and Theory of Machines, Paper 17. General Design, Piston and Turbine Engines, Paper 18. Piston and Turbine Engines; A. Romagnoli (Naples), Paper 14. Aircraft Design and Development A, Paper 16. Thermodynamics and Theory of Machines.

A. C. F. Visman (Delft), Paper 8. Aerodynamics A, Paper 9. Aerodynamics B, Paper 10. Aerodynamics C.

Society of Automotive Engineers' Meeting

The Society of Automotive Engineers Inc. (S.A.E.) will hold an Aeronautic Aircraft Manufacturing Forum and Aircraft Engineering Display from 29th September to 3rd October at the Ambassador, Los Angeles, California. Information may be obtained from the S.A.E., 485 Lexington Avenue, New York, 17.

Wilmot Breeden Fellowships

The Wilmot Breeden Group of Companies are sponsoring two Fellowships, each worth £1,000 per annum, one at the University of Birmingham and the other at the College of Technology. Successful candidates will divide their time between the University or College and the Company. Each Fellowship will normally be held for a period of two years. A candidate for a Fellowship should normally have had two or three years research or industrial experience. He must be acceptable to the academic authority and would be expected to have an honours degree in a University in the British Commonwealth, a Diploma in Technology, or an equivalent qualification. An application for a Fellowship should outline a two-year investigation or project on which the candidate seeks to work, and should be sent to the Secretary, Wilmot Breeden (Holdings) Ltd., Amington Road, Birmingham 25.

Journal Binding—New Prices

The greatly increased postal rates, together with other rising costs, unfortunately necessitate revised charges for 1958 for the permanent binding of Journals. The increases are 1s. 6d. on the 1957 volume and 2s. on previous volumes. The new charges are:—

1957 Volume (including packing and postage *in the United Kingdom*)	£1 4s. 0d.
Previous Volumes (including packing and postage *in the United Kingdom*)	£1 6s. 0d.

Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Members are asked to be certain that the address to which they want their Journals sent is the same on their letters to the Lewes Press and to the Society.

Self-Binder Cases

Self-Binder cases of the "Easibind" type to hold 12 Journals are available from the Offices of the Society at 11s. 6d. each (including postage *in the United Kingdom*).

Elections

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Charles Bayly
Peter John Bell (*from Graduate*)
Walter Lansdown Bennett
Raymond Alan Blythe
Anthony Frank Boot (*from Graduate*)
Stanley Butler (*from Graduate*)
John Chalmers (*from Graduate*)
Ronald Edward Clear
Michael Frederick Collins (*from Graduate*)
Derek Charles Crowther (*from Graduate*)
John Perran Curry (*from Graduate*)
George Kasin Ferris (*from Graduate*)
Roy Carruthers Fletcher
Vladimir V. Gencic
Bernard Austin Gittins
Alan John Goodwin (*from Graduate*)
George Kenneth Frank Green (*from Graduate*)
Norman Frederick Harpur (*from Graduate*)
Norman George Hatton (*from Graduate*)
Peter Ambrose Hearne (*from Graduate*)
Richard John Herbert (*from Graduate*)
Reginald Charles Hinton
Keith Frederick Hopkins
Percy Allardyce Hudson (*from Associate*)
Brian Reginald Charles Hutchings
Zbigniew Jawor (*from Graduate*)
Robin Edward Keates (*from Graduate*)
Leslie Robertson Logan
Gerald David MacDonald (*from Graduate*)
John Gilbert McDonald (*from Associate*)
Donald Lewis Matthews (*from Graduate*)
Nilal Shashi Prabhakar Naidu (*from Graduate*)
Leslie Frank Nicholls (*ex Graduate*)
Kenneth Tudor Owen (*from Graduate*)
Wilfred Adams Page
Michael Aubrey Perry
William Pitson (*from Associate*)
Stephen James Pooley
Donald Reeves (*from Graduate*)
Edgar James Roach (*from Associate*)
Eric William Rundle
Sheikh Mohammed Saeed (*from Graduate*)
Robert Emmerson Simpson
Eric Henry Smith (*from Graduate*)
Gerard Raphael Soffe
Peter Charles George Stalkartt (*from Student*)
James Donald Storer (*from Graduate*)
Ian Gourlay Strang (*from Graduate*)
Graham Robertson Stroud (*from Associate*)
Alan Bruce Thompson (*from Associate*)
Sidney Walmsley (*from Graduate*)
Ronald Sidney Williams (*from Graduate*)
Derek John Wood (*from Graduate*)
Percy Charles Wright
Hugh John Todd Young (*from Graduate*)

Associates

Victor Herbert Edward Denham
Stephen Baker Gibson
Raymond Ernest Gough
Richard Randall Harrison
Basil John Joint
Sidney Francis Paul
Ian Allister Virgoe Smith
Edward Arthur Stamp
James Webster Still
John Bernard Whittington

Graduates

Frederick Charles Bagley
Thomas Johnson Black (*from Student*)
John David Bromley
Brian Anthony Daniels
Ralph Samuel Davies
Kenneth James Dunkley
John Frederick Farley
David Norman Foster (*from Student*)
Christopher Francis Michael Glanister
Peter Hampton (*from Student*)
Christopher Harold Hansford
William Evan Hooper
Derek Iredale (*from Student*)
David Denver James
Thomas Iorwerth Young Jones (*from Student*)
Derek Stuart Kendall
David John Lloyd Lewis (*from Student*)
Samuel James Park Lyttle
David John McNally (*from Student*)
Sidney Malpass
Michael John Profit Hallahan Mercer (*from Student*)
Michael Murden (*from Student*)
Frank Malcolm Rands (*from Student*)
George Alfred Brian Seth (*from Student*)
Thomas Reginald Simes
Michael Richard Smith (*from Student*)
Somasundram Soundranayagam
Stanley William Tubbs
Peter Waring (*from Student*)
David James Macdonald Webster

Students

Alastair William Rodney Allcock
Edwin Richard Allen
David Martin Ashford
John Allan Bailey
David Leon Bower
Leslie John Stanley Bradbury
Peter Godfrey Buxton
Malcolm John Crocker
William Gresham Cuff
William Barron Dent
Robert Burns Campbell Elliott
Alexander David Finlay
David Malcolm Foster
Avyang Raghoba Gauneker
Peter Gaunt
William George Gillies
Amos Ginsburg
Bruce Anderson Graham
Jeffrey Green
Roger Guest
John Duncan Harrison
Peter Hewson
John Charles Hitch
Janet Elizabeth Howard
Michael Gerald Howard
John Victor Hughes
Charles George Keil
Ian Drummond Lawrie
Richard Lay
Robert Martin Lynn
Richard Clive Maitland
Ramkrishin Arjandas Malkani
Nicholas Ronald Mann
Richard Peter Gibson Marus
Nigel John Mortiboy
Adam Antoni Nowak-Przygodzki
John Nigel Oliphant
William Keith Osborne
Anthony Noel Scott Parker-Ashley
Richard John Dicketts Poole
Roger Pope
Gordon Francis Regan
Leo John Schefer
Robert Sopher
Patrick Michael Gordon Spence
Roynen Titchen
James Stuart Tucker
John Nigel Waddington
John Walter Lester Warren
Christopher Bernard Wheble

Companion

Joseph Louis Detraz

Income Tax

In response to enquiries from members with regard to a rebate on Income Tax for their subscriptions, the following is a copy of a letter received from the Principal Inspector of Taxes.

Ref: H.R.S.54/C.I. 4420/63.

14th August 1928.

Dear Sir,

Further to your interview with Mr. Stoneley at this office on the 19th July I am now in a position to inform you that the Board of Inland Revenue will not raise objection to the allowance as an expense for Income Tax purposes of annual subscriptions paid by members who are

(*i*) assessable under Schedule D of the Income Tax Acts in respect of professional or trading profits, subject to the decision of the Commissioners who make the assessment that such subscriptions are sufficiently closely related to the business carried on, or

(*ii*) assessable under Schedule E in those cases only in which continued membership of the Society is an essential condition of the terms of appointment.

Yours faithfully,
Signed: GEO. WILCOCK,
Principal Inspector of Taxes.

Secretary,
Royal Aeronautical Society.

Waverley Gold Medal Competition

The Waverley Gold Medal Essay Competition, designed to emphasise the importance of the clear presentation of scientific material is being held again in 1958. The Gold Medal and £100 will be awarded for the best essay of about 3,000 words based on some recent scientific research or new development (whether the author's work or not) giving some indication of the scientific background, the experimental results and its potential application in Industry. There will be a second prize of £50 and an additional prize of £50 for the best entry from a competitor under 30 years of age. The closing date is 31st July 1958, and full particulars may be obtained from the Editor, "Research," 4/5 Bell Yard, London, W.C.2.

The Journal of the Royal Aeronautical Society

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

VOLUME 62 APRIL 1958 NUMBER 568

SIR ALLIOTT VERDON-ROE, O.B.E., Honorary Fellow

1877 - 1958

ALLIOTT VERDON-ROE was born on 26th April 1877, at Patricroft, near Manchester.

He was educated, first at a boarding school at Shepperton, not far from Brooklands, and then at St. Paul's School, which he left before he was fifteen.

Among his father's friends was a civil engineer living in British Columbia, who offered to teach the young Roe surveying. So, after an undistinguished early education, A.V. set out—alone—on the long adventurous journey across the Atlantic and Canada. It was in that year—1892—that the then young Griffith Brewer published a long critical account of Hiram Maxim's giant aeroplane; when Lawrence Hargrave began his famous box-kite experiments in Australia; and when Baden-Powell declared "It is one thing to draw diagrams showing the way balloons ought to go, but quite another to handle a flabby bag of gas when you have it some 3,000 feet above the earth's surface."

A.V. arrived at Victoria, Vancouver Island, only to find that a slump in the price of silver had caused considerable unemployment, and surveying was not much in demand. After a spell of tree planting, fishing, and part-time Post Office worker, he returned home and at 16 was apprenticed in the Lancashire and Yorkshire Railway Locomotive Works. There he clocked in at six in the morning and out at 5.30 in the evening, for five years.

He learnt much heavy engineering, much human kindness and understanding, and gained proficiency certificates from the Mechanics Institute. After a passing visit to Portsmouth Dockyard on torpedo work, he went to King's College in London, to study Marine Engineering, hoping to enter the Navy. Although he passed in mathematics and technical subjects, his general subjects were not so satisfying to the Naval authorities, but proved good enough to enable him to become an engineer on a British and South African Royal Mail Company's boat.

It was during his last voyage in 1902 that A.V. decided to enter the non-existent aeronautical industry. On that voyage he had made many gliding models, and though they rarely behaved as he had expected them to do, yet they provided him with sufficient evidence to give him his unbounded confidence in the future.

He was then twenty-five years of age.

Alliott Verdon-Roe.

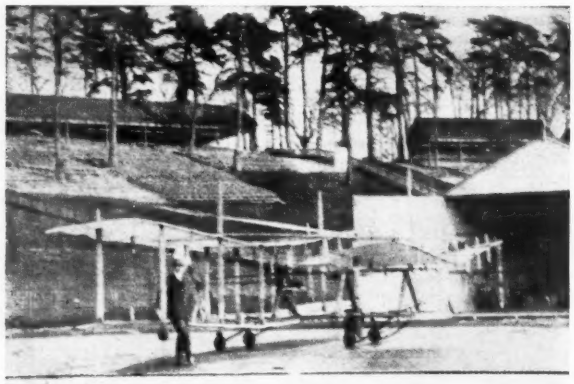
At the end of 1902 he became a draughtsman in the fledgling motor car industry, adding to his engineering experience. But all his spare time was given over to model aeroplane making and flying.

At the end of 1905 his pioneering flying instinct became too strong to ignore any longer. Boldly he wrote to *The Times*: —

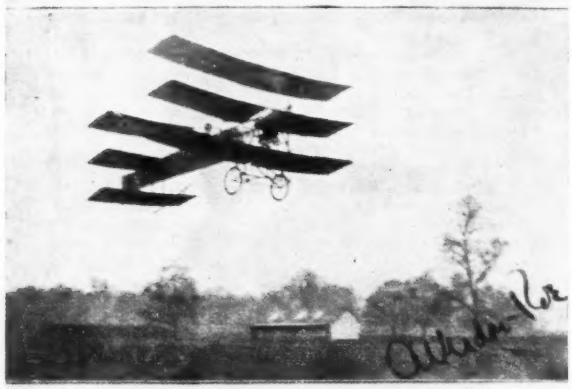
"It may be news to some of your readers to learn that flying with heavier than air type of machines is an accomplished fact," he began. "I allude to the Wright Brothers 24½ miles in a motor driven aeroplane. Although great publicity does not seem to have been given to the fact, it is nevertheless one of the greatest achievements of the time . . . .

"I have made some very successful steering glides with three feet long gliding models fitted with combined vertical and lateral rudders . . . If immediate steps are taken I see no reason why a motor driven aeroplane should not be gliding over England by the end of September."

The editor of *The Times* passed the letter to the *Engineering Supplement*, whose editor added a footnote.



Patented 1906. The first free Aeroplane to leave the ground in Britain.



The "AVRO" Plane flying with only 14 h.p.

A postcard with two photographs of Avro aeroplanes published by A. V. Roe and Company about 1909. This card is autographed by A. V. Roe in the bottom right-hand corner.

"Whilst giving that encouragement to new enterprise, denoted by the admission of what is patently free advertisement to our literary columns, it is not to be supposed that we in any way adopt the writer's estimate of his undertaking, being of the opinion, indeed, that all attempts at artificial aviation on the basis he describes, are not only dangerous to human life, but foredoomed to failure from the engineering standpoint."

That was the kind of encouragement given to aeronautical pioneers!

The Times made generous amends for their words on 6th January 1958.

"Perhaps no man has higher claims than Alliott Verdon-Roe to be called the Father of Flying. He was not the first to fly by five years, but he was the designer who set the fashion in aeroplanes which the world was content to follow for many years. He was the first Englishman who designed his own aircraft and flew it, and, as his designs were of more value to the world than the designs of those who preceded him, he deserves the highest honour of all."

In March 1906, as a result of his letter, A.V. was asked by G. L. O. Davidson to make the drawings for a big helicopter he had designed and intended to build in Denver, Colorado. Davidson had been persuasive enough to interest Sir William Armstrong of Armstrong Whitworth, to back it. After a short while in Denver, working on the drawings, A.V. tried to persuade Davidson that the fixed wing was a better proposition. Davidson's answer was to send him back to London to prepare the patent drawings, after which the two men went their different air ways.

On 18th November 1906, A.V. wrote to Baden-Powell, President of the Society.

"I am very anxious to join someone in making and experimenting with a motor driven aeroplane, and now you are going in for this perhaps we could come to some arrangement, or do you think I could join the staff at Aldershot?

"I am 29 years old, very active and have had 12 years engineering experience, including drawing office and college. The last three years having been spent in the motor industry, I am a first class driver mechanic and so am well suited for this new mode of locomotion."

Baden-Powell replied that he was no longer at Aldershot, but offered to help in any way he could. But the real turning point came when the *Daily Mail* offered substantial prizes in a model Aeroplane competition. There was an entry list of 200. The highest prize awarded was won by A.V. On page 233 is a facsimile of A.V.'s letter of 16th April 1907 addressed to Baden-Powell describing two of his models, the winning one flying a hundred feet.

A full-scale copy of the winning model was hand-made by A.V. in his brother's coach house at Putney. A pusher, with a four-wheeled undercarriage, it embodied ideas in advance of their time. The forward elevator could be warped or have its angle of incidence changed by a single control column, the first of its kind. Roe's 1906 patent No. 26,094 antedated that of Esnault-Pelterie by some twelve months. He made his own hollow rivets out of copper tubing; and his own wire strainers, which were afterwards manufactured by the hundred thousand. Everything he could streamline to lessen head resistance, he did.

On 14th August 1908, he wrote to Wilbur Wright, then at Le Mans in France. He began by saying he had won the model flying machine competition in 1906, and continued: —

"I then built a full-sized machine entirely alone, but have great difficulty with the Brooklands track manager, as he used to point out to me every now and then 'It was a motor car track, not an aeroplane track.' I was only allowed on the track between 9 and 10 in the morning and was not allowed to make a section of the rails detachable, which would have enabled me to take my aeroplane on to the track unassisted, whereas it had to be lifted over some 8 foot gate posts, a difficult task for eight people. So I managed to carry out my trials in the early hours before the officials were about by detaching some railings. Some friends used to smuggle themselves in the night before a trial.

Tel 2334
1 Victoria

47, West Hill.
Wandsworth S.W.
16th April 07.

Dear Sir,

Many thanks for your kind congratulations.

With reference to our models it is hard to say which is the better best.

The rear tail one, the first we built inside (¾ wound up) weighed 6 lbs complete, surface 20 sq ft. (not including tails as these do not rest on the air but the air beats against the upper side counteracting the forward weight, the two supernumerary planes acting as a fulcrum, this gives an automatic balance. This weeks "Motor" gives a fairly full description of my machines.) upper main plane 9ft x 15", lower 7ft x 15" rear tails (two) 12" x 24" each, with about 15" space between. weight of rubber 1lb. Dia of propeller 22"

The two forward steering aeroplanes weighed about 6lbs. the one tested inside with the large forward plane 7ft x 15", two main 8ft x 15" each, total surface 23 sq feet nearly ¼lb per sq foot. speed about 10 m.p.h. propeller 22" dia

Unfortunately the other smaller forward plane machine was not tested, owing to lunch time coming on this machine was just on 100 ft outside, after the crowd became unmanageable & the flight was not resumed. although Mr Roger Wallace said they would take it into consideration. This machine is practically

Steers about 12 ft in a circle

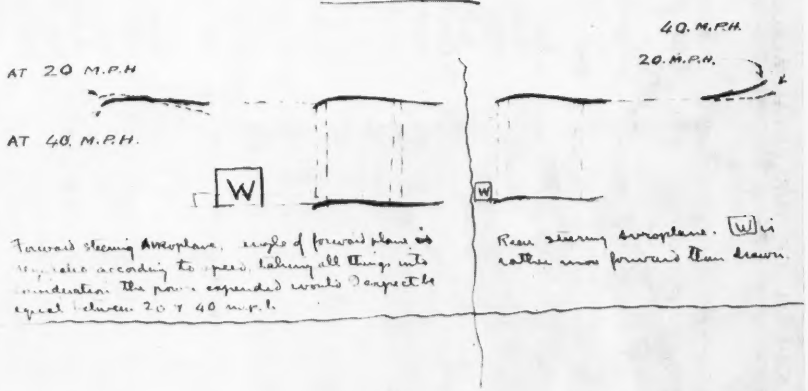
2.

similar to the latter but forward plane is 5ft x 12", two main being 8ft 6 inch x 15".

The forward plane machines go much slower than the rear tail owing to the less weight per sq foot, also these machines are beautifully steady. I think the rear tail type is perhaps the most stable in winds.

I am in favour of a high speed and small pitch for propeller, although I hardly followed this practice up in my models.

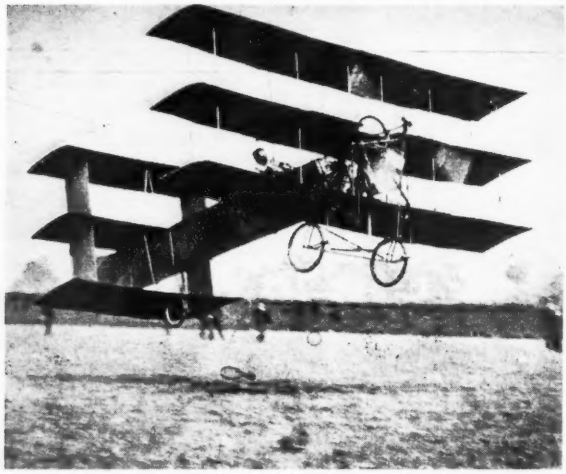
Yours faithfully
A. V. Roe



Forward steering Aeroplane. angle of forward plane is regulated according to speed, taking all things into consideration. The power expended would be expected equal between 20 & 40 m.p.h.

Rear steering aeroplane. W is rather more forward than drawn.

A. V. Roe's letter of 16th April 1907 to Major Baden-Powell.



The Roe Triplane, 1909. 9 h.p. J.A.P. engine. Flying on Lea Marshes.

"In all I managed to get six trials since receiving the 18/24 h.p. Antoinette engine last May and was fast making progress when I had to leave in July, the excuse being they wanted the ground my shed stood upon . . .

"I managed to make several flights towed by a motor car, the power required being very slight. At present my machine is detached and stowed away in the coach house here" (that belonging to his brother at Putney).

The manager at Brooklands in 1907 was more noted for his loud voice and lack of imagination than for any understanding of what was to come. Speaking of those early days at Brooklands, Lord Brabazon, at a banquet to the pioneers in 1920 commented: —

"I and my friend Mr. Roe went down to Brooklands—one might think we were looked upon with enthusiasm by some people—but nothing of the sort; people came long distances to see a couple of aerial lunatics; and though our machines had a small chance of ever leaving the ground I remember Mr. Roe's chief worry was not how he was going to get off the ground, but how he was going to find his way to Manchester."

A.V. experimented at Brooklands against difficulties and in circumstances which would have defeated any one with less vision and determination. He lived long enough, however, to see those much maligned days of aeronautical endeavour commemorated in aeronautical history when the name of the manager at Brooklands had been lost in the limbo of forgotten things.

Forty-seven years after he had been told to pack up and go, Vickers-Armstrongs (Aircraft Division) which had taken over Brooklands, lock, stock and motor track and all, had the graceful idea of erecting a granite plinth by those historic railings. It bore the following wording: —

"From this area on various dates in 1907-08, A. V. Roe made a series of towing flights and flight trials with an aircraft of his own design and construction, powered in the later trials by an 18/24 h.p. Antoinette engine. These trials were made along the finishing straight of the motor racing track on this site.

"A. V. Roe became the first of the long line of famous pioneers and pilots of many nations who made air history on this flying field of Brooklands.

"This tablet was placed here in June 1954 by Vickers-Armstrongs (Aircraft Division) and was unveiled by Sir Alliott Verdon-Roe, then in his 78th year."

Memories are short. Here British aviation first fluttered its tiny wings; here one man was harried from track to railings and finally roughly told to go, and be quick on the going.

Here, after two world wars, this man returned, smiling gently, to unveil his own memorial before an audience from which were missing so many who should have been there to pay him high tribute.

Before A.V. left Brooklands in 1908 he became airborne along the finishing track for a distance variously estimated at between 75 and 150 feet.

"I cannot adequately express my feelings in words as I realised I was clear of the ground, not only with my front wheels as I had been before," he wrote in his autobiography, "but with rear ones, too, for a space of quite 3 feet appeared between my front wheels and the ground and at the same time I had an exhilarating feeling of conquest."

This was the first time a British-designed and British-built aeroplane had got off the ground under its own power, piloted by its designer and constructor. A.V. records that several more attempts were made with very much the same results the same day. His brother H. V. Roe recorded in the *Journal* of the Society for April 1910 that "It was on 28th June 1908 that he made his best flight. This was about two feet off the ground for about 60 yards."

It is odd, in the controversy which came about in later years, that this letter was never referred to, at any rate publicly.

When he left Brooklands, A.V. went back to his brother's coach house in Putney and began the construction of a triplane to be powered with a 9 h.p. JAP motorcycle engine. He was refused permission to carry out trials with his machine by the War Office on Laffan's Plain, where Cody was carrying out his aeroplane trials; and by other bodies which had control of wide open spaces. Finally he was allowed to rent two railway arches at Lea Marshes and to gather round him one or two enthusiasts with even less money than he had.

One of them was Howard Flanders, who was to become a well-known designer himself in the next year or two. Flanders gave a lecture in January 1924 to the Institution of Aeronautical Engineers, on the early days of aviation.

"The triplane was a curious construction showing much originality," he said, "and more nearly resembled modern machines than any other aeroplane of that date.

"The Lea Marshes was far from being an ideal aerodrome. The ground was divided by three fences. The two parts near the railway arches, which served as

hangar and workshops, were covered with stumps of wood, used to tether donkeys and goats . . . .

"Those were days of toil. Every hop meant a crash. The procedure was as follows. At 4 or 5 a.m. we assembled and carefully wheeled the triplane out of the railway arch down the tow path beside the river Lea—a difficult job as there was a small gate to pass through and the tow path was narrow. Having pushed the triplane to a suitable corner of the ground, amid the jeers of the onlookers, we endeavoured to start the engine, which usually took 15 minutes.

"Mr. Roe, having given the word 'Let go,' all his assistants seized tools, pieces of timber, and other appliances, to repair the inevitable smash. One kept a cycle with a fire extinguisher handy and followed as closely as possible in case of fire, which was not infrequent. When the landing took place after a hop, which might be anything from 10 to 120 yards, if a miracle had occurred and the machine was still intact, the process was repeated until the inevitable crash took place. We then partly dismantled the triplane and carried it home amid further jeers from the onlookers. The work started and we worked for days in the very damp and dark railway arches to prepare for the next crash. The average programme was two weeks' work, a 50 yards hop, crash, and work again.

"At first no one with any sense stopped to watch the madmen, but after M. Bleriot had crossed the Channel we had another difficulty—that of sightseers. On one occasion the trams and buses were stopped and the police complained, so Mr. Roe had police persecution added to his other difficulties."

What a magnificent and unconscious tribute to A.V. and all his helpers in those exciting hours of the birth pangs of flight in this country. They were, indeed, the golden hours of flight, with the vision splendid before their eyes, when records were not important and the money that was spent was one's own scarce and hard-earned money, when they could

". . . . meet with Triumph and Disaster,
And treat these two imposters just the same."

A.V.'s father and brother had helped to finance their aeronautical relative. But at the end of 1909 H. V. Roe, who had a factory in Manchester, offered to join with his brother to form Avro & Co. and to supply a workshop in his own factory. The company was formed in January 1910.

A.V.'s triplane had brought him fame, if it had failed to bring him fortune. At Lea Marshes he had flown with a 9 h.p. engine, and in June 1909 with a 14 h.p. engine he made many successful flights at Wembley.

In 1909 there came a change of management at Brooklands and A.V. was invited to return there, soon to find so many whose names became as familiar as household words, Sopwith, Grahame White, Gordon England, Cody, Howard Wright, W. O. Manning, Martin, Handasyde . . .

↑ A. V. Roe ↑ Spottiswoode ↑ Martin ↑ Handasyde

A group of pioneers at Brooklands in 1911, taken by W. O. Manning.

The Avro Monoplane, 1912. The first cabin machine flying at Brooklands.

At the Blackpool flying meeting of 1910 substantial prizes were offered and A.V. packed the two triplanes the firm had, and sent them off by train. In 1928, in his autobiography, he related what happened.

"When I arrived at Blackpool it was to hear the tragic news that both the railway trucks had been ignited by sparks from the engine and their contents utterly destroyed."

That was Wednesday evening. The flying meeting was due to start on Monday, August Bank Holiday.

"We had a few odd bits of aeroplanes lying about so decided to build another and worked with hardly any rest until the Saturday evening. On Sunday we took the machine to Blackpool, arriving in late in the afternoon . . . .

"The engine arrived at 10 o'clock on Monday, and by two o'clock the machine was in the air. Being Bank Holiday there was a large crowd. They little realised their danger. It was the worst machine we ever built. The engine rev'd in fits and starts. I unwillingly got over the cheering crowd, undergoing great difficulty in steering the machine, and managed three circuits, landing inside the course. My willing helpers had a busy time, for I had three smashes."

But it seemed in those days that the more smashes A.V. had, the more determined he became to fly without them.

A day or two after the Blackpool meeting closed he sailed to Boston, Massachusetts. He had sold a triplane to the Boston Aeronautical Society and had agreed to fly it. In doing so he added three more to his score of crashes, the last one landing him in hospital.

By this time he decided he had had enough of triplanes, although not enough of flying. His next machine was a biplane, a tractor powered with a 35 h.p. Green engine.

In 1912 A.V. designed a new type, fitted with a 50 h.p. Gnome engine. It was a two-seater with dual control. The following year the Avro 500 was designed. It was the genesis of the Avro 504 and was first tested at Brooklands in 1913.

The late R. J. Parrott, A.V.'s first technical assistant at Manchester, in a lecture on 9th January 1925, on the Avro 504 machines, said: —

"It would be idle to state that they were determined by abstruse stability calculations, because, in 1913, although theoretical mathematical research into these questions had been made, the findings were not in such a form as to be suitable for use by the aeroplane designer . . . . The principal dimensions of the Avro 504 were arrived at by our previous experience and Mr. Roe's extraordinary instinct in these matters. As our experience has increased it has become a matter of amazement that these proportions were so good, the more so as we have proved that they were really quite critical."

The monument to A.V.'s memory must ever be the Avro 504.

Of it, in his autobiography, he wrote, "I think I ought to point out, in view of the fact that various people have been mentioned as being responsible for this machine's design, that I not only drew the original general arrangements, the plans of which I have in my safe at home, but practically all the details."

Fifteen years later he wrote to J. M. Bruce of the 504, "I still have my original rough pencil sketch on ¼ in. squared paper which started this aeroplane."

This is not the place nor the space to elaborate upon this astonishing aeroplane. The papers by H. M. Bruce, which first appeared in *Flight* in July 1954 are exhaustive. Now added to, and published in book form, they form a study of the military aircraft of the 1914-18 War without parallel in aviation history.

Flown by E. P. Raynham, the 504 was tested officially at Farnborough in November 1913, reaching a speed of 80·9 m.p.h., with a stalling speed of 43 m.p.h. A passenger and three hours fuel were carried.

In 1914, before the outbreak of war, the War Office ordered 12 machines, and the Admiralty one, to make the military dozen. Naturally the Navy wanted a different internal structure from the Army, despite A.V.'s efforts to persuade them that it would help production to keep the same standard.

The Avro 504, modified, re-engined, and increasing rapidly in production, played its part in the first air war, beginning with the bombing of the Zeppelin sheds at Friedrichshafen in November 1914 by the first four machines to be delivered to the Navy.

The design ran through the 504A to 504J, "which" to quote Bruce, "deserves to be remembered as the aeroplane which made possible the RAF's system of flying training, a system which, at its inception, was far ahead of any other method of instruction . . . . On it the late King George VI learned to fly, and it was standardised as the training plane. Modified, for various engines, it became the famous 504K."

I cannot better Bruce's words to finish this all too brief note on A.V.'s masterpiece.

"In one form or another, Avro 504 gave service somewhere in the world until the outbreak of the Second World War . . . . Its ubiquity was perhaps inevitable, but that alone cannot account for the very real affection with which it is regarded by all who flew it. One or two 504K's are, fortunately, with us still and one at least is occasionally airborne; but British skies are the poorer now that they are no longer graced by the elegant form and dignified progress of this great aeroplane."

A worthy tribute to A.V.

In 1912 A.V. designed a cabin monoplane and biplane, the forerunners of the aircraft of the future. The cabin biplane was entered for the Military Trials of 1912. With F. P. Raynham as pilot it established a British duration record in October 1912 of over 7½ hours. Fitted with floats it was the first British seaplane to get off the water.

On Friday 8th June 1928, on the initiative of Lord Sempill, then President of the Royal Aeronautical Society, Alliott Verdon-Roe was honoured with a banquet given jointly by the Society, the Royal Aero Club, the Air League and the Society of British Aircraft Constructors, "in recognition of Mr. Roe's pioneer work on machines of his own design and construction, and of the great debt which British Aviation owes to him during the past twenty years."

In the Chair at this gathering from all sections of the aeronautical world, was that generous patron of aviation, Sir Charles Wakefield.

"This is an occasion of great importance to the history of aviation," he said, giving the toast of the principal guest. "We are assembled tonight to pay long overdue honour to a man who has left his mark on world aviation. Mr. Roe has become famous in spite of that characteristic handicap of true genius—modesty. For all the long years during which he has been applying his unique inventive powers to the problems of aviation, he has been content to let his actions speak for him—and they have spread his fame far and wide . . .

"Tonight we have in our midst a man of our own kith and kin, who, gifted with exceptional genius, courage, and determination, has won immortal fame by his creative work in an entirely new field of endeavour . . . ."

That year A.V. sold his interests in the Avro Company to Mr. John Siddeley (later Lord Siddeley) and bought an interest in S. E. Saunders Ltd. of Cowes, which changed its name to Saunders-Roe. He had an unswerving faith in the flying boat, and urged their merits in the public press and elsewhere. The great concept by Sir Arthur Gouge of the Princess flying boats gave him a particular pleasure and disappointment, as they have done to so many.

Alliott Verdon-Roe spanned the lifetime of British aviation as one of its leading figures.

He was a very gentle man, with a gentle smile which betrayed his deep sense of humour, and hid the determination which drove him ahead in the most adverse of circumstances.

In a broadcast tribute, R. H. Bound, who had worked with him, told how A.V. had the happy knack of being able to work *with* his staff, as one of them, and keep them as happy as himself. He was the first in his office, in which he had framed the notice:

> Work eight hours a day and do not worry and eventually you will become a boss and work eleven hours a day and have all the worry.

A.V. was a *working* pioneer, by which I mean he could make, mend and do in order to carry out the ideas which required so much of those skills.

He joined the Society in 1909, was knighted in 1929, and was elected an Honorary Fellow in 1948.

J. LAURENCE PRITCHARD.

Lord Sempill writes:—

The aviation world rightly mourns the loss of Sir Alliott Verdon-Roe as the greatest British pioneer of flying, because he was the first to build and fly his own aeroplane in this country. He designed the Avro 504 bi-plane on which the

The original Avro 504.

whole foundation of modern flying training was built. He retained an active interest in aviation to the end of his life, yet this is but one facet of a truly remarkable man, who was loved and respected by all with whom he came into contact and not the least by one of his many pupils.

He was very much a family man, the kindly father of nine children, and the sort of employer who could often be found taking his midday meal in the works canteen of his factory because he enjoyed being among engineers.

Two photographs taken in the garden of his home last October when he was in his eighty-first year typify A.V. as he will be remembered by his friends. In one he is sitting on the handle bars of his bicycle that he designed himself riding it backwards to show that he never lost the skill, energy, and puckish humour that made him an outstanding racing and trick cyclist in the 1890's. The other photograph shows him in the two wheel car which he designed and built in the meticulously neat workshop that occupied a corner of his garage. This "bi-car" looks rather like a motor scooter, but contains many advanced ideas, and is so designed that it provides considerably more protection against the weather than the ordinary scooter. The fact that it was a single-handed product of an octogenarian is perhaps less remarkable than that it is almost identical with a similar machine built by A.V. 36 years ago, and which was the forerunner of every scooter now on our roads.

A.V.'s inventive mind was never still. When the fire in his study refused to draw he simply put a fitted metal plate in the chimney that speeded the draught with almost the fierceness of a blacksmith's forge. Among many useful things, he devised a tap from which the washer could be changed without turning off the water, and anti-dazzle headlights for motor cars.

Books and diaries in his neat handwriting contained countless ideas and suggestions of commercial value, but the most important by far to A.V. personally was a large and much battered desk diary in which he noted "passing thoughts" from 1947 until September of last year. Headed typically "where there is no invention the people perish," the contents range over a variety of topics, but the great majority are concerned with high finance, for A.V. devoted much of the latter part of his life to a crusade for monetary reform.

In brief, he considered that most of the world's financial, social, and other problems stemmed from the fact that international economy is based largely on debt fostered by the cheque system. He advocated that money should be created and controlled by the State rather than by the bankers, that business prosperity and personal happiness would be increased if enough money were issued to enable everyone to buy freely the results of a full production programme by industry and agriculture, and that profit-sharing should be extended. He recalled that Abraham Lincoln before he was assassinated had similar ideas which might have had untold effect on the future of a civilization now weighed down with taxes and economic crises, and that another great engineer, Henry Ford, commented "money is just a part of our transportation system to move goods from man to man, it breaks down so often that it is time our financial engineers developed a new model."

Because of his ideas on currency reform many persons regarded A.V. as a crank. His good natured reply was that he was considered not merely a crank, but a public menace in 1909 when he flew his pioneer triplane on Lea Marshes, yet now that little triplane is one of the most treasured exhibits in the Science Museum at South Kensington.

From *The Times*, 27th January 1958.

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The Presidential Address

An Address by the President, Sir George Edwards, C.B.E., B.Sc., F.R.Ae.S., was given before a large and distinguished audience of members and their guests at Church House, Westminster, London, S.W.1, on 26th February 1958. Lord Hives, C.H., M.B.E., B.Sc., LL.D., *Honorary Fellow,* presided. At the end of the Address the second part of the Shell Petroleum Company's film "High Speed Flight—Part II. Transonic" was shown for the first time.

Following the Presidential Address a Reception was held by the President and Lady Edwards at the offices of the Society, 4 Hamilton Place, W.1, which was attended by over 500 members and their guests.

LORD HIVES, opening the meeting: I have been given the privilege of introducing tonight the President as the Speaker. Now it is not a very difficult job, one thing it does not impose upon you to look back into records to find what his contribution has been to aviation. Your President's reputation is secure and recognised in all countries.

I think without any exaggeration I can claim that no one man has done more for civil aviation in this country. The Viscount is recognised as the Standard Bearer for our future of exports of aircraft. The Viscount is one of those unusual products in which the customers enjoy it, the operators enjoy it, the constructors enjoy it and I am sure the Government must enjoy it because they have had a most successful return on their original investment.

The other thing which I think we should keep in mind is that of the hundreds of Viscounts which have been sold, and it always gives you great joy to talk about aircraft in hundreds, they have all been bought and sold on the basis of a willing buyer and a willing seller; never once has it been necessary to consult the British Cabinet as regards whether the machine is the right one for the customer to have.

Your President is not only the creator of the aircraft, he has the much more arduous job of satisfying the customer and of course it is only by having a succession of satisfied customers that you can expect to have continuous business. Now apart from the Viscount and its continuing development, your President has created the Vanguard, which has already received a considerable export order and in order to make sure that he should not have any dull moments he has now gone ahead with the VC 10, which represents the last word in civil aviation.

All the things I am mentioning are in connection with civil aircraft, but he has also made his mark on the military side. The fact that one hears very little about the Valiant nowadays, I think you can take it that it is going about its job and it is doing its duty in a satisfactory way. We know our friends from the Press never miss an opportunity, if there are any difficulties with aircraft.

All I am saying to you is what you all know, but Sir George is very modest and it is necessary to repeat this kind of thing in order that it will be recognised.

I will now call upon your President to read his Address.

MAY I say first of all the honour that I feel at this large gathering and especially, the honour that Lord Hives has paid me in agreeing to take the Chair. This great man, described so rightly as the greatest British engineer, has been a personal friend for many years and I can think of no one whom I would prefer to Chair this, for me, great personal occasion, than Lord Hives.

This is the Fifth Presidential Address to be delivered before the members of the Royal Aeronautical Society; the first, in 1903, was by Major B. F. S. Baden-Powell, the second by Mr. H. E. Wimperis, who was President from 1936 to 1938, the third by Mr. N. E. Rowe in 1956 and the fourth by Mr. E. T. Jones in 1957. They can accept the responsibility for starting this modern revival. Those two very good friends of mine made addresses in which they reviewed the Society's aims and activities and its effect on affairs with a form of composition and a style of address with which I just did not feel capable of competing. But they had set the fashion and there was little escape.

After Mr. Jones' Address last year there were some first-class films and I discussed this idea with my good friend Mr. Ernest Bass, the Chief Engineer of Shell Aviation Department, because they are the makers of some of the finest films ever produced in the Aviation world and it subsequently developed to a point in which he and his Company paid me the great compliment of allowing this evening the second part of their series of films on High Speed Flight (this part is Transonic Flight) to be shown as a part of this Presidential Address. I have therefore achieved part of my object in avoiding some of the burden and reasonably ensuring some entertainment.

When this Address was far enough off that I was prepared to think seriously about doing some work on it, I was much taken with the idea of trying to give a message to people with the general object of convincing them—and me—that aviation had been, and still is, of great benefit to mankind. I was considering, in other words, taking on the role of super-salesman for aviation as a whole, rather than any particular type or make, which is my more accustomed occupation. It was also, of course, my job to tell you something of the work which the Society is doing and some of our hopes for the future. It seemed a pretty tall order to try to show the film, talk about the Society and, in the intervening time, deliver an oration on a subject beset with too many pitfalls for me to avoid them. The nature of the Shell film really turned my mind towards the subject finally chosen—the influence of speed on transport. As you might well expect, the treatment is not intended to show that if aviation produces speed, then speed is a bad thing. Although it is bereft of the grand sweep that my original idea had, maybe it can touch on one aspect of it.

Turning first of all to the affairs of the Society. One thing which happened during last year was the formation of a Guided Flight Section. This is a name intended to cover the activities of a group within the Society whose principal interests lie in the control and guidance systems not so far associated with manned aircraft and much more connected with the Guided Weapons field. The name Guided Flight was chosen after a great deal of deliberation largely because a number of the principles embodied in the control and guidance of guided weapons may well find their way, by stages, into the control of manned aeroplanes. Some of them indeed are already doing so. The name provided plenty of opportunity for people to argue, and from that point of view has achieved one of the basic requirements of a piece of successful publicity.

The Inaugural Lecture was given by Mr. Serby, the Director-General of Guided Weapons in the Ministry of Supply. It was a pretty lively occasion, as have been the subsequent gatherings and I think there is little doubt that the Council has achieved what it set out to do when it blessed the formation of this Section. It has infused into the old body some vigorous and worthwhile new blood which looks like making it hop and jump about in a most undignified and not very guided, but extremely healthy, fashion. As I have said, I personally believe that a great deal of this work which at the moment may be peculiar to the "guided weaponeers," in time will become integrated into the manned aeroplane—if there are any left to integrate it into.

Also during the past year, we have had the Sixth Anglo-American Conference which took place primarily in Folkestone and London, last year being our turn to be hosts to the Americans.

These Conferences allow engineers and scientists of Britain and America to get together and discuss their problems, both in the lecture hall and in informal groups outside it. They have been the means of bringing together a great many people with similar interests from both sides of the Atlantic and, I believe, have made a worthwhile contribution to the furtherance of those good Anglo-American relations which I believe to be the most vital thing which this country can preserve. The opportunity to demonstrate to our American friends some of the work we have been doing also enables us to let them see that we, too, have some fairly stubborn ideas and that, from time to time, we are doing all right as well. The opportunity has been taken during the past year (including at the Conference to which I have just referred), to remind them that in this era of turbine-engined transport air travel, the only turbine-engined transports which have flown a single hour in scheduled airline service have been British or Russian, with the emphasis predominantly British. This sort of thing has not been done just to make the Americans cross, but in the belief that real friendship is only worthwhile if it is based on respect, and on some demonstration of independence of outlook and approach. From my recent incursion into the American's camp I think I can report that the fact which we pointed out—namely that we are not completely stupid—has not done anything to weaken the friendship between us.

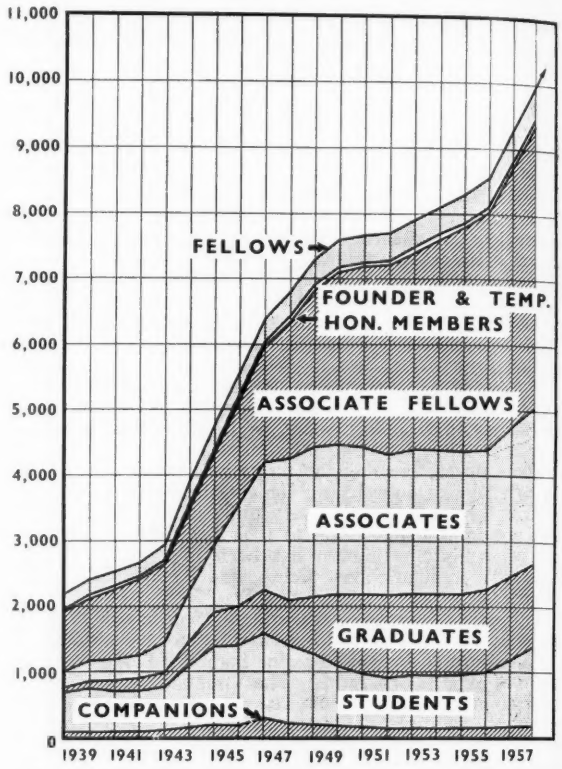

FIGURE 1 . The Royal Aeronautical Society membership.

Also last year was the second of the Air Transport Courses, organised by the Royal Aeronautical Society. I believe there is no conference comparable to this held anywhere else, and its success can be judged by the fact that the limited number of delegate places has been over-applied for several times. This Course enables students in the air transport business, both manufacturing and operating, to live together for three weeks and have lectures and discussions with experts in various fields of commercial aviation.

The Council have been actively pursuing the question of a permanent home for the Society. Our first ventures into this were obviously too expensive for the Society's finances to stand, but the new scheme recently announced by the Minister of Transport for the Hyde Park Corner area may make possible the thing which we would all most like—to build a lecture hall at our present very graceful premises at 4 Hamilton Place. Whether this will be possible it is much too early to say, but I can tell you that it is being actively examined.

The success with which the Society is conducting its affairs, a few of which I have just touched on, is difficult to measure by any single yardstick, but there is one, I think, which gives a good indication and that is the rate of growth of membership.

Figure 1 shows the rate of growth of members of the Aeronautical Society since 1939, and I would

remind you again that this old Society was originally formed as far back as 1866. You will see that at the beginning of 1939 the total membership was just over two thousand, but by the end of 1942 it had reached 3,000. From 1942 up to the end of 1946 there was a sharp growth to 6,500; then the post-war impetus of civil aviation and so on carried it up again to 7,600 at the end of 1949. The rate of increase then fell somewhat, and for a few years until the end of 1955, due to various causes, the membership increased by 1,000 only over the years 1949-1955. It is, therefore, especially gratifying to find, from that time until the present, the increase has been no less than from 8,600 to a figure (which we reached last month) of 10,000 members. I am especially fortunate in being the President during the year when the membership has broken through the 10,000 figure, but that has nothing to do with me. I believe the person to whom the greatest credit for this belongs is Mr. N. E. Rowe who, during his term of office, started off very actively a campaign for recruiting members from all round the country, which was followed vigorously by Mr. Jones in his term. So, without being complacent (because the future will hold a great many difficulties for us) I think you can look at that curve of membership with an annual net increase of 700 over the past two years, with the feeling that we are not doing too badly. The Chairman of the Grading Committee, Mr. Henry Gardner, tells me that there are no signs that their labours are being lightened and, at the moment, the indications are that this rate of increase will go on.

A point which I should make, and which I regard as being very important, is that this membership of 10,000 is made up of full members of the main Society. In addition to this, the Branches, of which there are 28, have a form of local membership to which the subscription as a rule is in the order of five or ten shillings. This enables people who are in the area of the Branch to attend the Branch lectures and take part in the activities of the Branch without becoming full members of the Society. There are approximately another 6,000 Branch members in addition to the 10,000 full Society members—so that the Royal Aeronautical Society, in one form or another, now reaches no less than 16,000 people.

During my term of office I have visited many of the Branches; and as recently as last week, we had the stimulating experience of hearing Marshal of the Royal Air Force Sir Dermot Boyle, Chief of the Air Staff, give the inaugural Trenchard Memorial Lecture to the Branch at the R.A.F. Training School at Halton. During my visits to the Branches I have been greatly impressed by the virility and enthusiasm which goes on there and I have no doubt that the strength of the Society lies in its Branches and not, as we can easily believe, entirely in London. There are, of course, Divisions overseas in the Commonwealth, where also very active work is being done—in Australia, Southern Africa and New Zealand and in the Branch at Singapore. In Canada there is the Canadian Aeronautical Institute, which has now been invited to participate in the next Anglo-American Conference.

The Influence of Speed on Transport

I now come to the second part of my Address. I am very well aware of the fact that there is nothing new in what I am going to say—it has been said before by a good many people—but the subject did seem to be a reasonable link between the affairs of the Royal Aeronautical Society and a film on transonic flight. I am going to try to show the way in which speed in transport has developed and the way that the demand for more and faster transport was stimulated by the world's communities becoming industrialised. Also that, in the same way, and in a kind of "chicken and egg" relationship, the presence of more and faster transport enabled the world's communities to become industrialised and to expand. You will not be surprised to find that some of my conclusions indicate that the further development of speed in transport is likely to rest with the aeroplane.

Figure 2 shows you what was going on, in Britain at any rate, at the end of the seventeenth century. The pedestrian in 12 hours (a day's journey time) could have gone 20 miles. The horse-rider, we have established, was able to do 30 miles in his day, which got him on the one hand as far as Reading or, in the other direction, a little beyond Maidstone. If you were rich, or alternatively ran an expense account, you could travel in the coach and do 75 miles in the 12 hour day. The team of assistants who carried out the researches which enabled this part of the lecture to be written at all, produced supporting evidence of these figures which, in themselves, would have formed the substance for half-a-dozen lectures. I very nearly abandoned this one early on so that I could spend the whole evening

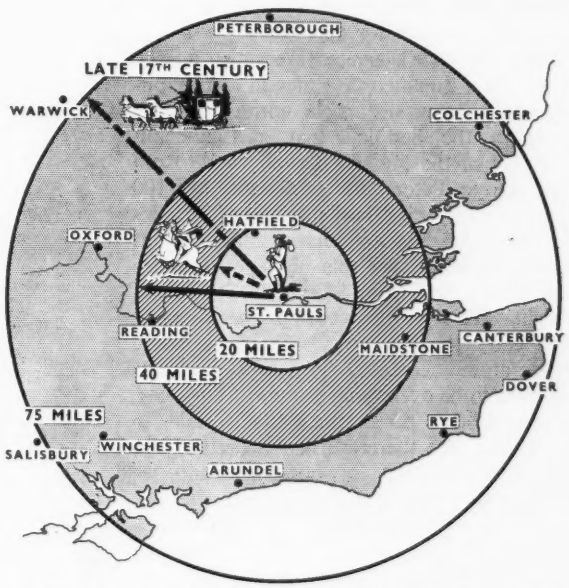

FIGURE 2. A day's travel before the Industrial Revolution.

FIGURE 3. A day's journey—1895 (from London).

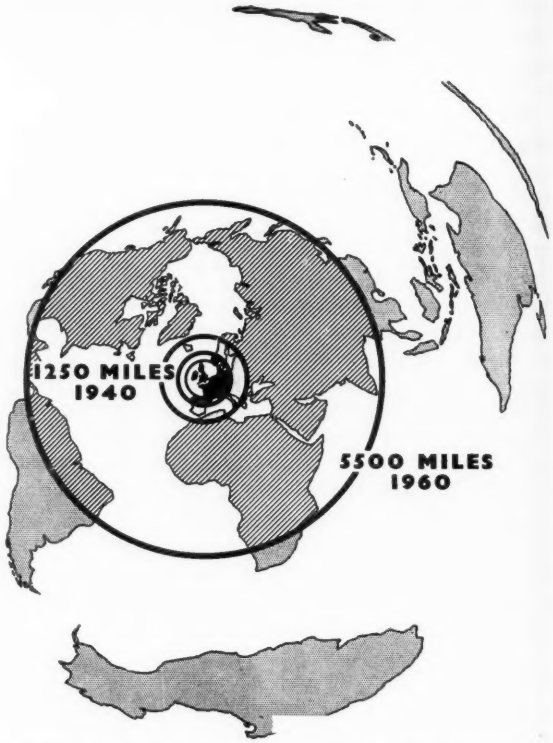

FIGURE 4. Progress in air transport. 12 hour journey from London.

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on a dissertation on the marching ability of the British Infantryman. Before the First War the Infantry did as much as 30 and 35 miles in a day, but that was a pretty long day. It began at four in the morning and did not finish until seven or eight in the evening. The Russians, who seem to have been pretty active in this as in other things, in 1769 had some of their troops doing between 20 and 30 miles in a day in all sorts of Russian weather—and one Russian army actually did 300 miles in 11 days. More recently, in 1957, the Women's Royal Army Corps actually did 24·855 miles in a day and they kept going for four days. So we thought that for an ordinary man in the 17th century —we would settle for 20.

The horseback figures are most interesting. The Blues did a dignified 20 miles in a day, but we found from an article entitled "Great Feats in the Saddle" that a Lieutenant Peschkof of the Russian Cavalry rode from Siberia to St. Petersburgh, a distance of 5,100 miles, at an average daily distance of 37 miles and on some days as much as 60 miles. It is worth noting that this high performance was done going from Siberia to St. Petersburgh. We have no record of how long it took going the other way. In India, where temperature accountability is a technical problem to be overcome, groups of horsemen were trained to do as much as 120 miles in 20 hours. We therefore had a pretty good spread in the way of horsemen and we decided to settle on 40.

The stage-coaches, in about 1650, were doing four or five miles an hour, but as late as 1700 it took a week to get from London to York, and a 75 miles circle might be a bit flattering there for 12 hours. With a touch of the advertising ballyhoo (which we have found present in more modern forms of transport) we discovered that the stage-coach of 1649 was said to achieve a situation whereby one might be " transported to any place,

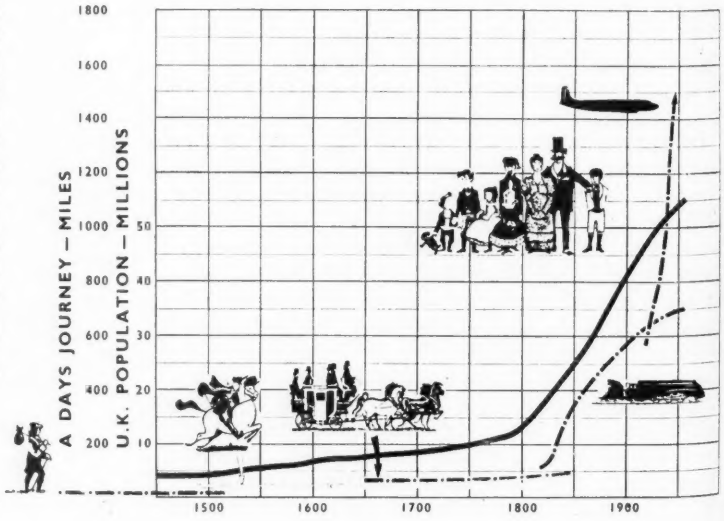

FIGURE 5. Growth of population—the stimulus to travel.

sheltered from foul weather and foul ways, and not only at the low price of about one shilling for every five miles, but at such velocity and speed in an hour as the foreign post can but make in a day."

Figure 3 shows that a hundred years after the end of the eighteenth century, a 12 hour journey covered pretty well the whole of Britain and also went into the Channel countries. Here in a day the distance had jumped, from the 75 miles in the previous figure, to 250 miles where water was in the way, and to as much as 550 where it was not. So that from the year dot until the age of the Industrial Revolution, 75 miles was as much as could be managed in a day. But stimulus of the Industrial Revolution during the nineteenth century produced an increase in the day's journey distance from that 75 miles to over 500.

Making a jump (Fig. 4) from 1895 to the present day we need a map that goes a bit farther than the one covering the Home Counties and a bit of France. We need one of the world. The series of circles on this represent the distances that you could go in a 12 hour journey from London. The centre circle represents when it was only 560 miles, no farther than you could go in 1895. This is a reflection of the fact that surface transport had not done much between 1895 and 1920 and air travel, of course, had barely started. The next circle (1930) shows the 12 hour distance up to 760 miles, the 1940 one is up to 1,250 (by which time we were covering a large part of Europe)—and by 1960, in which I have allowed myself the anticipation of the big subsonic jets, plus perhaps, a touch of optimism, the circle is 5,500 miles. The chief thing about this figure is not so much the distance that one can go in 12 hours in 1960, but the amount that still remains uncovered by a 12 hour journey from London. The distances before 1960 were all taken from air guides and air time tables. The 1960 figure may be 10 per cent optimistic due to routing.

With Fig. 5 I want to go back over the past 500 years again and draw your attention to the series of curves at the bottom of the chart, which show the way in which the day's journey time has increased over that period. We start off with the man on foot and his 20 miles and then the horseman doing his 40 miles, the stage-coach with its 75, and the railway train getting up to 700. This is followed by the dramatic rise in 12 hour's distance made possible by the advent of the aeroplane. Also on this chart, the upper curve shows

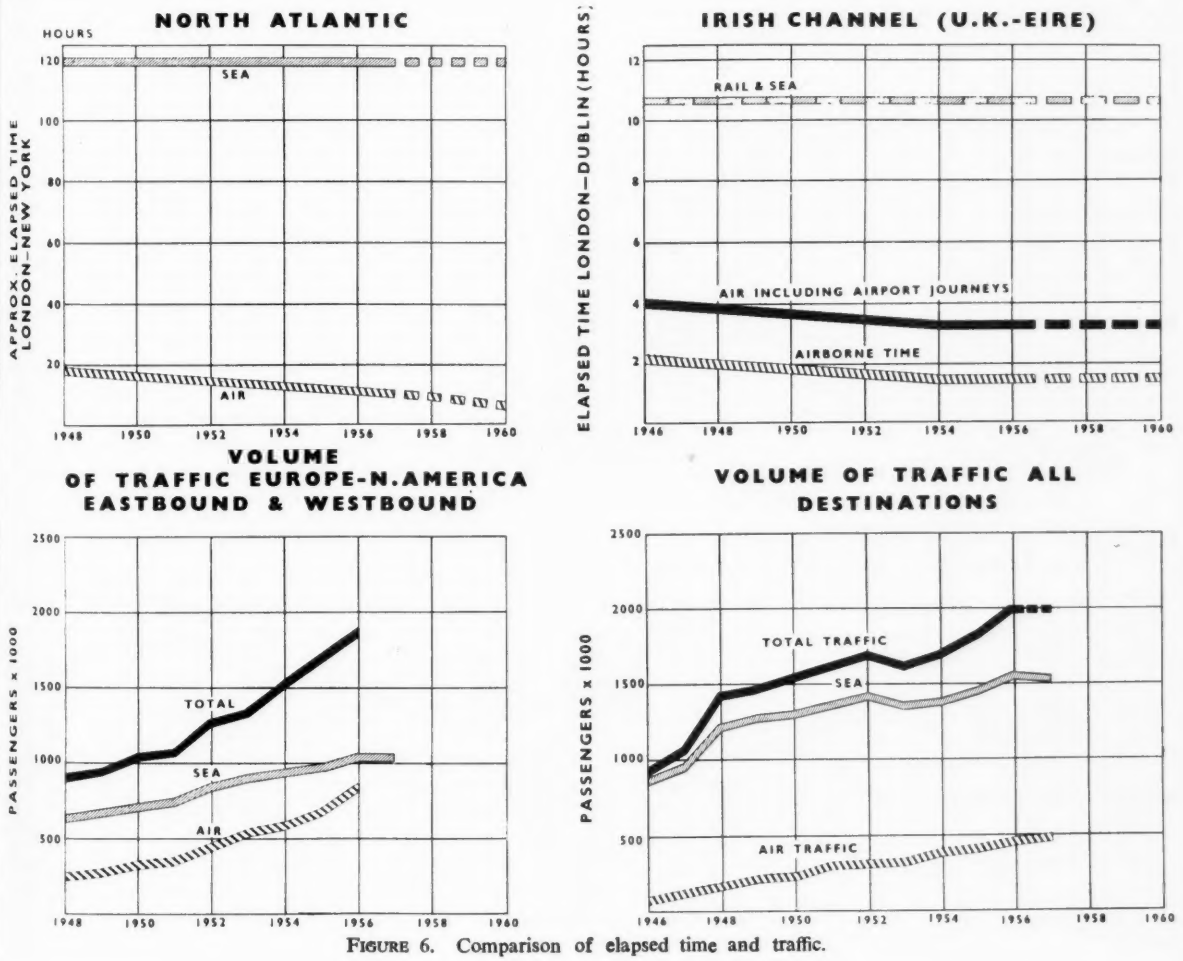

FIGURE 6. Comparison of elapsed time and traffic.

the way in which the growth of the United Kingdom population increased. The Industrial Revolution started shortly after 1800 and there is a sharp increase in the population growth curve. There is also a sharp increase in the distance of a day's travel. The inter-relation between these two could well be the subject of yet another lecture. It is clear that the increase in industrialisation which came with the Industrial Revolution, in turn brought about an increase in population, and a greater demand for more and faster transport. This increase in travel stimulated business and in turn increased industrialisation and with it, the population. The reference books are unclear as to why this sharp increase in population in fact took place at that time. The most likely cause is that the mortality rate, especially the great mass reducers of the population such as famine and plague, had been stemmed. The facts, however, are that the population did increase at the time of the Industrial Revolution and at the time of the increase in transport. It is pretty obvious that there is a definite connection between industry, population and speed of transport.

On Fig. 6, two famous routes are examined over the post war period—on the left is the North Atlantic and on the right the Irish Channel. The upper curve on the left shows how the time to get from London to New York has changed since 1948, with an extension on the air curve to 1960. The big difference between the time

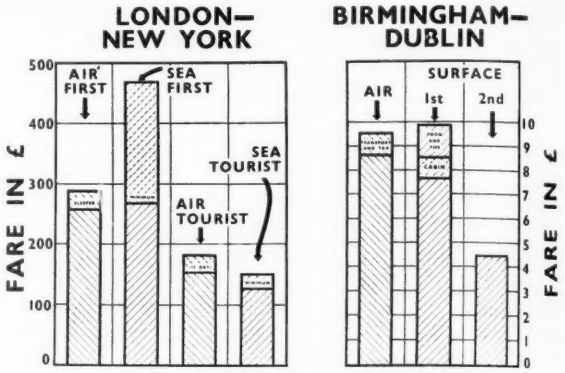

FIGURE 7. The cost of travel.

that it takes to cross the Atlantic by air and sea is shown quite clearly and needs little comment. The bottom graph shows the way in which the traffic which is carried across the Atlantic is shared between sea and air. In 1957 they carried a little over a million passengers each and the two curves, in fact, meet. The increase in air over this period is dramatic in that it has virtually quadrupled, but it is also interesting to note that there has been an increase in sea travel at the same time, although not nearly so great. It could be that the upsurge of air travel has had a stimulating effect on this total.

If we look at the Irish Channel, the upper curve there shows a comparable picture in that a journey by train and boat from London to Dublin takes 10 hrs. and 28 mins., whereas the air route from London to Dublin takes 3 hrs. and 10 mins. (centre to centre) a gain of 7 hrs. 18 mins. Looking at the lower curve it is clear that the total traffic, which has doubled, has been helped significantly by the attraction of the air route. This has grown from almost nothing to a quarter of the total travel. So summing up these four diagrams we have the position where by flying on the North Atlantic, you cut out nine tenths of the journey time and on the Irish Channel you can cut out two thirds.

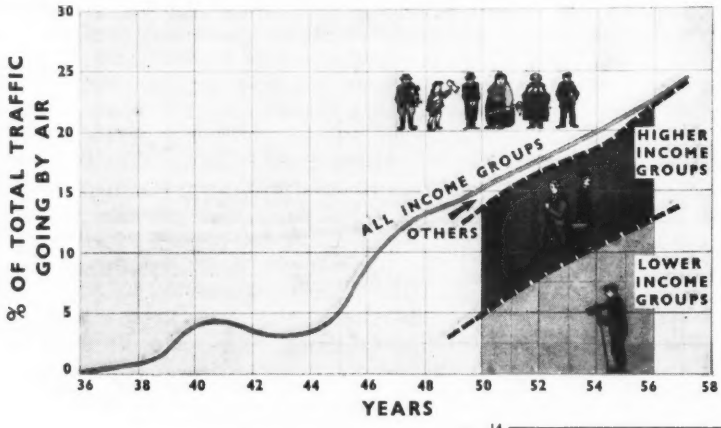

FIGURE 8 (*above*). Travel U.K.-Eire. Classification of passengers travelling by air.

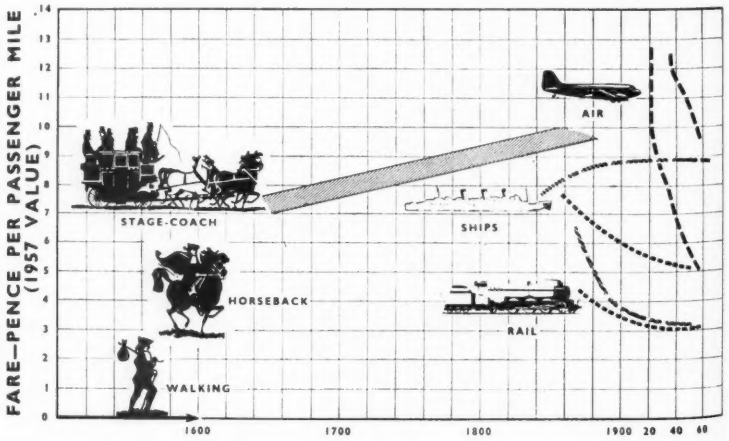

FIGURE 9 (*right*). What has it cost?

There is no good talking about speed unless one relates it to cost, and in Fig. 7 the cost of travelling across the Atlantic or to Ireland is shown. The thing that I want you to note is that air is not cheaper than sea on either London to New York, or Birmingham (I have chosen Birmingham for a reason I will explain later) to Dublin. In actual fact the cheapest form of crossing the Atlantic or going to Ireland is by surface travel. Now bearing in mind that the cheapest way to go to Ireland is by sea, Fig. 8 shows the Irish Air traffic subdivided into income groups. The interesting thing here is that the increase over the past seven or eight years has not, as you might expect, come from the higher income groups but has in fact come from the lower income group. The number of people in the higher income brackets stays fairly constant, whereas the lower income group figure has almost doubled over the past seven years. On the Birmingham-Dublin route the lower income group content is some 70 per cent of the whole. This, I think, is a pretty positive demonstration that speed will encourage travel, even though it will cost more, and I think another interesting thing about the Irish route is the fact that it is a short-haul unglamorous leg in comparison with the North Atlantic. This of course is the dramatic route always quoted for comparisons in time saved in travelling by air.

I should also deal briefly here with "Expense account travellers"—who, unlike the lower income groups, are not historically concerned with fare rates. Their journeys are "on the firm" and it is not surprising that speed is chosen every time. What does emerge from a general study of business travel, however (and this has been backed up by such figures as are published on this subject) is that when a destination gets beyond the 12 hour journey circle, journey incidence falls sharply. There is much business flying inside the "12 hour circle"—in fact half of it. There is a further one third on journeys of 24 hours and only one sixth to the more distant places—even though they include South America, Australasia, the Far East and a lot of South East Asia. There's a moral there somewhere.

On this "Cost of Travel" figure (Fig. 9) is pence per passenger mile, brought as far as we can up to present day values, with an indication of the way in which the various forms of transport have varied in cost. There is the pedestrian on the bottom, who does not cost anything. There is the horseman who works out at 4d. a mile; there is the stage-coach which started off at 7d. but cost more as time went on; then over on the right, are the bands of cost of rail, ships and air. These show that the air band is about on the same level as the seventeenth century stage-coach. What is most notable is the way in which increasing speeds in the air have been accompanied by sharp reductions in cost. So, for

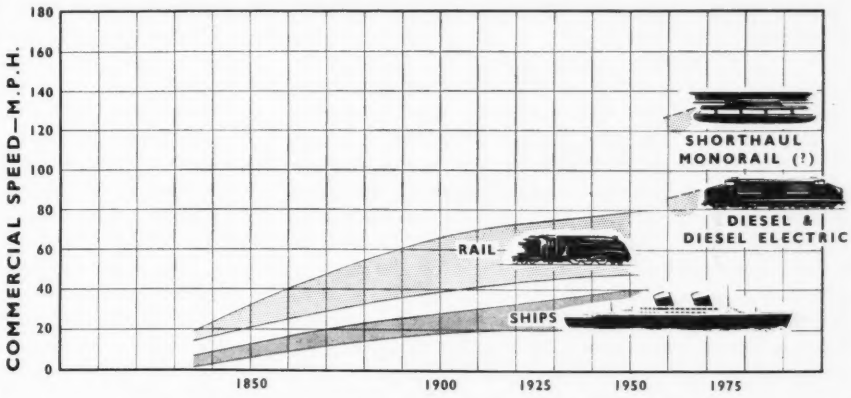

FIGURE 10. Relative progress, surface transport.

that matter to a lesser extent, have the rail and the lower orders of ship, although the upper ship curve has stayed pretty steady. But I think the way in which the technological improvements in aviation have brought reducing fares at the same time as increasing speeds is a most remarkable thing.

I propose to leave the question of cost with that figure and want to draw your attention (Fig. 10) now to the way in which surface transport speeds have developed (or not) over the past 150 years. Here you see the way in which ships and trains, especially the latter, developed fairly rapidly up to the early years of this century and then largely levelled out. The diesel and the diesel-electric have given a small increase and I include the possibility of the Mono-rail. This is a picture in general of speeds being limited by some

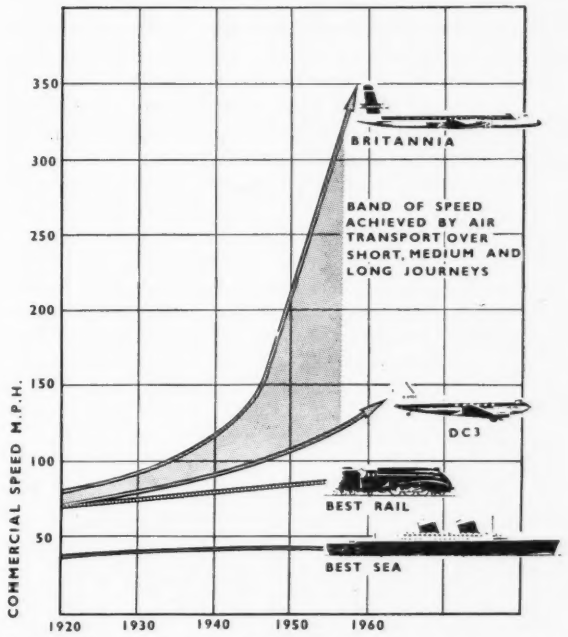

FIGURE 11. Air is the only free medium for progress. Progress in air transport speed over short, medium and long journeys.

artificial factors, such as those imposed by tracks and hull design.

In Fig. 11 you have quite clearly and, I think, on a conservative basis, the great strength of the aeroplane—its freedom so far from artificial restrictions on cruising speed. The band, ranging from the DC-3 at the bottom to the Britannia at the top, shows what is being achieved at this time by aeroplanes of all types on short, medium and long journeys all over the world. By 1960 you will be able to shoot that line further up to 500 miles an hour. I think some of the motive behind this talk will be coming clear. It is that increasing speed in transport has been the essential hand-maiden to increasing development all over the world and that the only medium in which speed can continue to increase is the air. There is no indication that a demand for increasing speed is going to diminish or disappear, so that the demand for faster aeroplanes is likely to go on. Having said that, let me make it quite clear that there will be, in my opinion, a whole lot of operations which are better conducted by an aeroplane not necessarily in the top speed range. The dramatic cutting down of journey time compared with that of surface transport is an advantage shared by all modern aircraft. We have shown that these big savings of time attract the traffic to the aeroplane as a vehicle, even despite higher fares.

The speed range of aeroplanes themselves is, however, scattered over a fairly wide band, but they all have, to a greater or lesser degree, a dominating speed advantage over surface transport. People—and I mean people in the mass—are preferring air travel. But—and this is an important point—having chosen to fly, the actual airborne vehicle selected will depend upon overall economies.

Speed increases in the air, up to now, have, by improvements in the state of the art and by much labour, always been accompanied by better economies and efficiency.

Any reversal of that trend would be a set back for civil aviation and would halt the present flow of mass travel towards the aeroplane.

Speed improvements as between aeroplane and aeroplane must be related to the job in hand and also to the economic "rate for the job." Speed by itself and for its own sake, can be a false god, and pursuit of it is unhealthy.

I believe there will, in fact, be significant speed gains for aviation—and I am about to evaluate their probable immediate size—but I do it with the warning that these gains must be based on sound overall economy and efficiency of operation. Without that twin basis we shall have left the main road of progress for a cul-de-sac.

We might now discard surface traffic and look at history, as far as the aeroplane is concerned. Fig. 12 shows three things—the upper curve is the World's Air Speed record; the middle one is operational bombers and the lower one is propeller-driven transports; the two short curves in between the last two representing the jet transport operation that there has so far been—the Comet and the Tu-104. Among the aeroplanes which have captured the World's Speed Record at any given time I would like to draw your attention to Reg Mitchell's Supermarine S6, to Carter's Meteor, to Sydney Camm's Hunter, to Joe Smith's Swift and Bob Lickley's Delta. The dark part of this curve denotes the era of the jet engine, previous to that they had all been propeller-driven, but the thing which really surprised me was the way in which an entirely new slope of curve had come about with the advent of the supersonic airframe. The Swift, a subsonic aeroplane, was pushed literally round the corner, but as soon as the genuine supersonic aeroplanes in the form of the Super Sabre and the Fairey Delta and the McDonnel Voodoo came into being, then the rate of increase was dramatically stepped up. On the other hand, the bombers (propeller-driven up to the post-war era and then jet-driven) had followed a more or less parallel path with the World Speed Record, although a stately distance away from it. The propeller-driven transports followed a very steady curve without any significant fluctuations. But the jet transports came into operation very close to the jet bombers. This, therefore, is the history of air speeds up to the present time. We have had a dramatic increase of as much as 50 per cent in the World Air Speed Record over the past two or three years, the steady line of progression of civil transport cruising speeds and, for that matter, of bombers. There has, however, been a stepping up of bomber speeds with the advent of the post-war B-45 and B-47s followed by the "V" bombers.

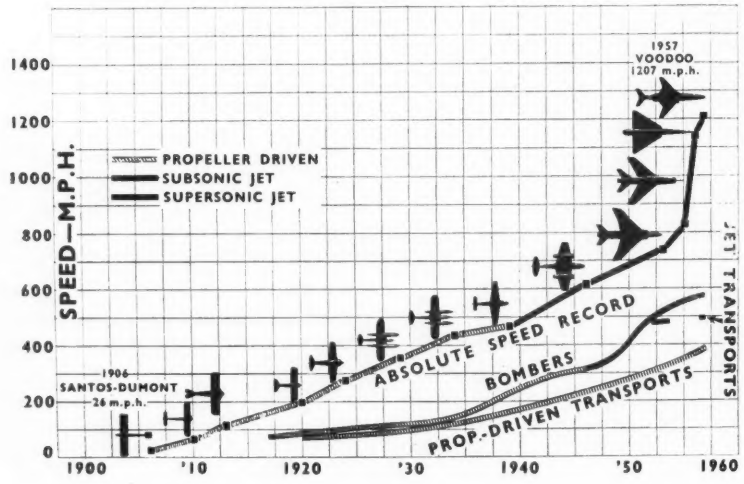

FIGURE 12. Speed trends.

In Fig. 13 I have taken the tail end of the previous one and done some extension into the future. The World's Air Speed Record I have left as it is. I have extended the bomber speed on the general supposition that by 1965 somebody could have a supersonic bomber capable of flying at a Mach number of 2·5 (although I have no idea if there will be such an aeroplane). I have extended the propeller-

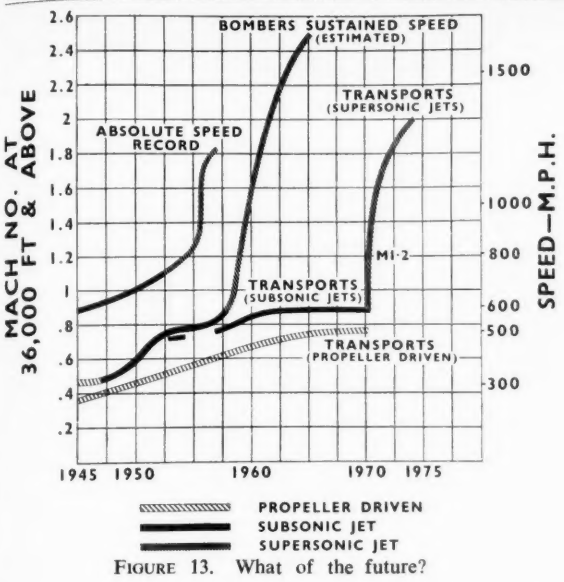

FIGURE 13. What of the future?

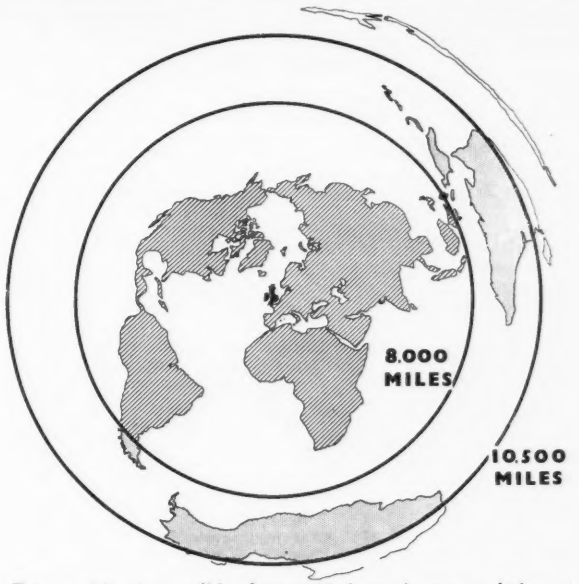

FIGURE 14. A possible future 12 hour journey, circles at $M=1{\cdot}2$ and $M=2{\cdot}0$.

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driven transport curve as a smooth continuation of the previous one and have not expected that the cruising speeds of propeller-driven transports will go above 500 miles an hour. Both of these assumptions I think were not terribly difficult to make, but I must say again that the bomber one is merely what I think could be done—I have no knowledge that it is going to be. The really difficult thing to do was to project the transport curve. Here I think we have to learn from the shape of the bomber curve and, before it, the speed record curve. It seems to me that the subsonic jets, such as the Boeing and the Douglas and the others, are in themselves going to produce something in the nature of a speed plateau and I think the airlines' financial situation will stop them being replaced for some considerable time. So I have ventured to say that subsonic jets will continue to do their 600 miles an hour or thereabouts right through the 1960's. There seems, however, to be no technical reason why the supersonic development of the World's Air Speed Record (and the supersonic bombers which could follow it) could not also be followed by supersonic transports, flying at speeds of over 1,000 miles an hour. If one decided that the previous gaps which had existed between the World's Air Speed Record and bomber speeds and transport speeds would be maintained, then there is no reason why civil jets should not be in existence at supersonic speeds in the 1960's. I believe, however, that the financial burden of depreciating the subsonic jets will alone make that impossible, and a supersonic jet in operation before 1970 is of academic interest only. When we do get a supersonic jet we get with it the ability to bring practically the whole world within reach of the 12 hour journey time.

I have tried to show that there is an increasing demand for a longer distance to be flown in 12 hours. I am certainly convinced that nothing will stop the ultimate operation of long-range supersonic civil aeroplanes. I believe that the operating costs when the time comes will be within reasonable distance of the operation costs—as we know them—of the subsonic jets. If I may hark back to my early word about our friends, the Americans, and the position that we the British hold today in the West—we have all the operating experience in turbine-engined transport with a propeller-turbine or pure-jet and I see no reason why we should not have our own great stake in this new field of supersonic civil travel. In my audience tonight are many important people who will have the responsibility of making decisions that will decide whether in fact there are to be British supersonic transports. If I have done something in this lecture to demonstrate that those decisions should be taken with a view to ensuring that there will be, then my time will have been well spent. If it is true that we are not going on with a supersonic long range bomber, then let us spend the money on a supersonic long range transport. This should not be hampered by following the basic design for a specialised military application in which economy is not a major factor. Let us make a virtue of necessity and put our effort into an optimum civil aeroplane.

I now have pleasure in showing the Shell Film Unit's production, "Transonic Flight," which will show some of the problems now being solved and many which still remain to be solved before our supersonic civil aeroplane will be carrying you, or your children, a lot farther in 12 hours than you can go at the present time.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the following:—

A.B.C. Railway Guide	Fare rates and journey times.
A.B.C. Air Guide	Fare rates and journey times.
Aer Lingus (Statistical and Market Research)	Passenger sampling figures and volume of traffic surface and air U.K. - Eire.
Atlantic Passenger Shipping Conference	North Atlantic Passenger figures (sea).
J. Bartholomew and Son Ltd.	Permission to use World Air Map.
B.O.A.C.	Fare rates and journey times:— 1932 to date—U.K. - Capetown. 1946 to date—North Atlantic. 1920 onwards—European.

British Railways	Trend of speeds on British Railways, also fares. Route considered: London - Edinburgh. Additional information on fares.
Central Office of Information	Population statistics, British Isles.
Cunard White Star	Historical fare rates on N. Atlantic from 1920.
French Railways	Average and best speeds currently achieved on French Railways.
I.A.T.A.	North Atlantic Passenger Traffic.
Imperial War Museum	Marching and Riding speeds.
Jane's All the World's Aircraft	Dates of introduction to service and characteristics of aircraft.
National Maritime Museum	Trans - Atlantic shipping, 1750.
P. and O.	U.K. - Australia fare rates and journey times, 1852 to date.
Royal Aero Club	Absolute air speed records.
Science Museum	Historical Trans - Atlantic ship speeds and passenger capacities.
South Africa House	Population statistics, South Africa.
Union Castle Line	Fare rates and journey time, U.K.-Capetown, 1915 to date.
U.S. Embassy	Population statistics, Eastern U.S.
United States Line	Journey time for *S.S. United States*, Southampton - New York.
Westminster Bank. Economic Intelligence Dept.	Conversion of old fare rates, and so on. Decided to use the Bank's methods.

A vote of thanks was proposed by Dr. G. W. H. Gardner, C.B., C.B.E., B.Sc., D.Sc., F.R.Ae.S., Member of Council of the Society, and seconded by Mr. J. R. Cownie, B.Sc.(Eng.), Grad.R.Ae.S., Member of Council.

DR. G. W. H. GARDNER: It is my privilege to propose a vote of thanks to the President, and I find this an easy task, in the sense that I can be entirely wholehearted and sincere, although I am sure I am unable to express my feelings in a manner fitting to the occasion.

At the outset, I would like to say how pleased the Society is to have Lord Hives in the chair tonight. He has already been aptly described by our President as the greatest British engineer, and we are very pleased that he has agreed to play a prominent part in honouring another very great British engineer.

We have heard a most inspiring address, presented in the manner peculiar to our President, with a mixture of wit and sober judgment using the simplest of words and phrases. Even in Moscow, just over a year ago, he overcame the communications difficulty by inventing a special language which was a conglomeration of British and Russian phrases including a good deal of Edwards slang. It was quite clear that this helped the Russians quickly to appreciate his sincerity and his sense of humour, and I think some phrases which he coined will remain in the vocabularies of those Russians whom he met, and will help them to remember our President with respect.

I am glad the President referred in his address to the new Guided Flight Section. We had further evidence last night of the healthy nature of this new offspring of the Society. In spite of the appalling weather, an audience which nearly burst the bounds of Londonderry House turned up to hear Mr. Boswell of Australia deliver his lecture on guided flight trials and they were well rewarded.

It is always tremendously interesting to see curves of the kind which the President has shown us tonight. While the shapes of the curves relating to flying are unique in the various fields of transport, they are remarkably similar to curves which I saw recently and which were presented by Dr. Sinclair of Magdalen College, Oxford. These curves depicted the growth of coronary thrombosis in this country and of the incidence in Glasgow of bone fractures. The similar shape of these two curves led to the deduction that lack of unsaturated fats was the cause of both troubles. I wonder whether there is any corrollation beyond the similar shapes of the curves between the incidence of coronary thrombosis and the speed of air travel?

The culmination of the President's Address was his declaration of faith in the supersonic, long-range transport aeroplane. There are many who will be fortified and encouraged to hear the argument advanced so convincingly by such an eminent authority, and it is to be hoped that the message will reach all those who must provide the wherewithal to convert this declaration of faith into reality.

Our President is not only a great engineer but he is a good ambassador. I have referred very briefly to his visit to Russia and he has referred, too modestly, to his recent utterances to American audiences. It warmed our hearts and encouraged us to learn that the facts were being put to our American friends in such a forthright and unambiguous way. In the course of these utterances, he has paid generous and well-deserved tributes to the Britannia and the Comet, and indeed to the Tu-104. The very fact that they were not relatively over-emphasised did not reduce our awareness of the outstanding achievements of the Edwards' stable.

I have referred to Sir George Edwards as our President, as a great engineer and as a good ambassador, and I would now like to say a few words about George Edwards, the man. Because of his great human characteristics as much as of his professional achievements, we are proud this year to have him as our President. I am sure the Society would wish me to thank him for his period of service which, with magnificent and gracious support by Lady Edwards, has been performed in a manner which cannot fail to add lustre to, and enhance the prestige of, our Society. During the First Lord Trenchard Memorial Lecture recently at Halton, the Chief of the Air Staff quoted Lord Trenchard's definition of a gentleman as one who knew how to look after his subordinates. This, perhaps more than any other, is the outstanding human characteristic of George Edwards. It springs from his high integrity, his fund of human understanding and his sense of loyalty and consideration for all those who, in any way, depend upon him.

On behalf of you all, I propose that this vote of thanks be carried in the spirit of great respect and deep affection.

MR. J. R. COWNIE: As a representative of the younger members of the Society, I am very pleased to have been asked to second the vote of thanks to Sir George.

Sir George's Address was a fascinating one and I am sure that everyone here tonight will be encouraged by his views about the Society's future. The suggestion of a lecture hall at 4 Hamilton Place is most welcome. Let us hope that this will come rapidly to fruition.

The figures Sir George gives for membership of the Society are most interesting. It is obvious that the membership has increased regardless of ups and downs in the aeronautical world. I am sure that this trend will continue. Although fewer aircraft may be built in future, those that are built will require much greater technical effort than the aircraft of the past. This applies particularly to the supersonic air liner that Sir George mentioned. Let us hope that serious work on this will not long be delayed.

There is no doubt that the younger members of the Society are confident about the future. Today the Society has more Students and Graduates than ever before and they make up no less than 25 per cent of its membership.

There is little I can add to Dr. Gardner's remarks about the excellent work Sir George has done for the Society. I think we owe a great deal to him for his realistic and down-to-earth approach to matters. It is a revelation to me to see how rapidly he gets to the heart of a problem and is not deflected by any red herrings on the way.

I have very great pleasure in seconding the vote of thanks to Sir George tonight.

The First Trenchard Memorial Lecture

Lord Trenchard

by

MARSHAL OF THE ROYAL AIR FORCE SIR DERMOT BOYLE, G.C.B., K.C.V.O., K.B.E., A.F.C., CHIEF OF THE AIR STAFF

The First Trenchard Memorial Lecture, "Lord Trenchard," was given by Marshal of the Royal Air Force Sir Dermot Boyle, G.C.B., K.C.V.O., K.B.E., A.F.C., Chief of the Air Staff, at the R.A.F. Station, Halton, on 20th February 1958. This was the 30th main lecture of the Society to be given at a Branch and was held under the auspices of the Halton Branch. The large and distinguished audience included The Dowager Viscountess Trenchard and the present Lord and Lady Trenchard, Sir John Nott-Bower, Commissioner, Metropolitan Police, the Mayor of Aylesbury, a number of members of Council of the Society, the Commanders-in-Chief of Fighter Command, Technical Training Command, Maintenance Command and Home Command of the Royal Air Force, the A.O.C.s of No. 24 and No. 41 Group, the Commandants of Andover, Bracknell, Cranwell and Halton, and many other serving officers of the Royal Air Force.

Group Captain A. K. Hunter, O.B.E., A.F.R.Ae.S., Chairman of the Halton Branch, opened the meeting by introducing Air Vice-Marshal H. D. Spreckley, C.B., O.B.E., F.R.Ae.S., Air Officer Commanding No. 24 Group, and Vice-President of the Halton Branch.

AIR VICE-MARSHAL H. D. SPRECKLEY, C.B., O.B.E., F.R.Ae.S.: Before the business of the Society proceeds from the platform, I as Air Officer Commanding No. 24 Group on behalf of myself, the Air Officer Commanding-in-Chief, Technical Training Command, Air Marshal Sir Arthur McDondald, and the Commandant of this Apprentice School at Halton, Air Commodore Nelson, wish to offer a hearty welcome to the Main Society and the guests here tonight.

We feel particularly honoured that the Halton Branch of the Royal Aeronautical Society and Halton should be the place chosen for this first Trenchard Memorial Lecture.

We are deeply touched—Lord Trenchard was the main architect of the Royal Air Force College at Cranwell and the Halton Apprentice School, the latter now having been running for 37 odd years. What more appropriate than to have this lecture given by the Chief of the Air Staff here, where Apprentices in the main aeronautical trades are taught and from where thousands have joined the Service and entered the aeronautical world at all levels. Indeed, an apprentice from this school has by his efforts in the field of research and development transformed and revolutionised the performance of aircraft.

I now hand over to the President of our Halton Branch of the Royal Aeronautical Society, Air Vice-Marshal Silyn-Roberts.

AIR VICE-MARSHAL G. SILYN-ROBERTS, C.B.E., A.F.C., F.R.Ae.S.: My duties this evening as President of the Halton Branch of the Royal Aeronautical Society are prescribed by the wishes of the Main Society and can be fulfilled with few words. First, I wish to place on record the feelings of the Halton Branch on this unique occasion. The Royal Aeronautical Society is paying tribute to the memory of the greatest military airman of all time. He was the first President of the Halton Branch and remained its President until the end of his life. The Branch concurs with pride in the fitting decision of the Main Society to hold the inaugural lecture at Halton. We, as a Branch, are proud and happy to welcome the Main Society to Halton.

It now only remains for me to introduced the President of the Royal Aeronautical Society, Sir George Edwards, who will then assume control over the proceedings. The President is a well known personality; he is not only a man of international reputation but also, a man who has contributed valuably over many years to the efficiency of the Fighting Service to which the majority of us in the Halton Branch belong.

It is a real personal pleasure to me to be given the privilege of introducing to you Sir George Edwards, President of the Royal Aeronautical Society, and inviting him to take over the meeting.

SIR GEORGE EDWARDS, C.B.E., B.SC., F.R.Ae.S.: First I would like to thank Air Vice-Marshal Silyn-Roberts for his introduction. I too have a great personal pleasure in coming here and seeing him again and so many of my old friends in the Air Force. I think this is one of the most stimulating tasks that I have had during my term as President of the Society. The first job I had was to take the Chair at the first of another Memorial Lecture—the Lanchester Memorial Lecture—which in its way honoured a great Englishman, and tonight we honour another great Englishman with this the first Trenchard Memorial Lecture. It has become the practice for Branches to inaugurate a Memorial Lecture in honour of an eminent man connected with them, and the first of these is a main lecture held at the Branch. This is so this evening, and I am grateful to Air Vice-Marshal Spreckley and those concerned for making the arrangements so successfully for the Main Society's Lecture here this evening.

I have no need to dwell on either the man about whom the lecture is to be, or the man who is to give it. The lecture is entitled simply "Lord Trenchard," from which it will be clear that the Chief of Air Staff is going to talk about Lord Trenchard. I believe that if he had been able to choose who should deliver this first lecture Lord Trenchard would have the man who is the first Chief of Staff to come from Cranwell, in the formation of which Lord Trenchard played a great part with the foresight that characterised his activities. It is my great pleasure to introduce to you Marshal of the Royal Air Force, Sir Dermot Boyle, Chief of the Air Staff. It would be wrong for me to try to describe to you at Halton, of all places, Sir Dermot Boyle's career and his distinctions; he is a great distinguished Officer and I have no words to add to that which you already know of him.

Introduction

I regard it as a great privilege to give this first Trenchard Memorial Lecture—and how appropriate it is that the subject should be the life of the person in whose memory this series of lectures has been inaugurated by the Royal Aeronautical Society.

Any lecturer would be proud to have such a splendid subject but its very magnificence places a great responsibility on me today. I realise that it is impossible to do full justice to the man about whom I am going to talk and that I must in some way restrict the scope of this lecture or it will never end. I am therefore going to concentrate on Lord Trenchard's work in relation to the Royal Air Force and merely touch on his other activities sufficiently to emphasise how diverse and effective they were.

"We should be modest for a modest man as he is for himself." quotes Sir Walter Raleigh, the first Historian of the Royal Air Force, when speaking of Trenchard as Chief of the Air Staff in 1920, and I know that Lord Trenchard himself would have wished me to keep this ever in mind in the substance of this talk. Nevertheless, let me say at the start that he was a giant among men—great in heart and mind as he was in stature. One point will emerge: his was not one career but many—and he left his mark upon them all. He was Soldier, Colonist, Airman, Policeman and Business Man. Before ever he became an airman he had a career behind him in the Army, of which many a man would have been content to boast in retirement.

Courtesy of "The Aeroplane"

Marshal of the Royal Air Force, Sir Dermot Boyle, G.C.B., K.C.V.O., K.B.E., A.F.C., Chief of the Air Staff, delivering the First Trenchard Memorial Lecture. Inset: The bust of Marshal of the R.A.F., Lord Trenchard, first Chief of the Air Staff, which was in front of the dais.

Army Service

Although it is with the Airman that we are now mainly concerned, some background of his early life will not come amiss. Commissioned into the Royal Scots Fusiliers in 1893 after passing through the Militia, he served in India until the South African War brought him to action. He fought with all "sorts and kinds of irregular forces"—Imperial Yeomanry, Australian Bushman Corps and the Canadian Scouts. Soon after being promoted Captain in early 1900 he was severely wounded in the lung during the operations west of Pretoria. Not surprisingly out of action for several months, he nevertheless returned to the fray, this time with the mounted infantry in the Transvaal, Orange River and the Cape Colony.

In 1903 he was seconded as a Brevet Major to the West African Frontier Force and thus began his great interest in, and knowledge of, the problems of West Africa. His service in Nigeria was notable; he received the award of the D.S.O., was twice mentioned in despatches and had command of the Southern Nigeria Regiment from 1908-1912. Then he was invalided back to the United Kingdom.

At this point, any lesser man's military career might well have ended—and extremely honourably—but he was too energetic to retire and, indeed, he never did retire. So while his applications to return to another overseas post were being considered in the War Office, the death in a flying accident of an old friend of his, Eustace Loraine, turned his mind towards this new field. In view of his age the War Office gave Trenchard ten days to learn to fly, so he took himself to Brooklands to the School run by T. O. M. Sopwith; he passed his tests within about a week and took his Certificate on the 13th August 1912 in a Farman machine. Six months later was his 40th birthday, and he would have been too old for the new Service; I cannot imagine how the Air Force would have fared if it had been so arbitrarily deprived of so great a champion.

The Central Flying School*

Trenchard went to the Central Flying School expecting to be a student but was surprised to find himself appointed Chief Staff Officer to the School, of which the Commandant was Captain Godfrey Paine, R.N. Thus it was that he, in his own words, "wore a Navy cap and Army spurs." He owed his new position in great measure to being a Brevet Major and, on looking up his duties, he discovered that among them was the setting of the examination and deciding whether or not those who sat for it had reached the required standard. Within a fortnight he had set himself papers on aerodynamics and the mechanics of flying, had examined himself and declared himself to have passed. Thereafter he was wont to observe that, as long as he was at the School, he was determined to maintain the same high standard in all examinations. The truth was that he was no great believer in written tests, holding that practical experience was of far greater importance.

*These reminiscences of the C.F.S. were taken down by Hilary St. G. Saunders.

Air Ministry photograph, Crown copyright

Marshal of the Royal Air Force Lord Trenchard, the First Chief of the Air Staff—the portrait by Vertilleux.

In his flying instructor, Lieutenant A. M. Longmore, R.N., who eventually retired as an Air Chief Marshal, Trenchard found a friend ready and eager to give him the experience he sought. The two men flew as many hours together as they could snatch from their duties.

On one such flight during the autumn manoeuvres of 1913 they were forced to land in a field and broke the tail boom of their Farman. In gathering darkness the local blacksmith spliced it together with a metal sheath. At frequent intervals during the next morning the imperturbable Longmore would ask, as they lurched along, whether the tail was still there. Trenchard, who was navigating, lost his way and they landed to make enquiries. The usual crowd which aircraft attracted in those days assembled and gave well-meant but confused directions. Having chosen a course, the airmen took off through a press " of people, pigs and chickens " and duly arrived at their destination. Here they became the object of the pestering admiration of numerous " flappers " carrying autograph books. " I don't know what name Longmore chose," said Trenchard afterwards, " I signed each book ' W. Smith'!" So much for the early days of flying.

Thus it was that Hugh Trenchard was closely associated with the very cradle of the Royal Air Force right back in those early days of the C.F.S. By the outbreak of the 1914-1918 War a great proportion of the officers of the R.F.C. had passed through his hands. " His," said Sir Walter Raleigh, " was the policy of Thorough." The efficiency of the Flying Corps, at that time and in its own way another of the irregular Forces towards which Trenchard always seemed to be drawn, was to become the efficiency of the Royal Air Force.

Perhaps one thinks of Trenchard as an administrator rather than a flyer and yet, in those early days with records being made and broken almost weekly, Major E. L. Gerrard and Trenchard together reached 10,000 feet and broke the British height record.

The First World War

When war came in 1914 the existing squadrons hurried off to the front and in a short time there remained practically nothing in the way of aircraft or pilots in the country. Colonel Trenchard, as he then was, stayed behind at Farnborough in charge of the Administrative Wing of the R.F.C. " to create something out of nothing." But he did not remain there for long, for with the reorganisation of the R.F.C. in France he was given command of No. 1 Wing at St. Omer in November.

In August 1915 he succeeded General Henderson in command of the Royal Flying Corps in France.

Under the somewhat forbidding exterior, Trenchard was the great gentleman, true always to his own definition of a gentleman—a man who knows how to treat his subordinates. Maurice Baring, who was his Secretary and personal friend for many years, recorded that, when he was interviewed for the position as Secretary, Trenchard told him that he was " not so bad a person to serve under." In fact, he was a man of gentle ways who found himself regretting an argument as soon as it was over—one which he had probably won. His inherent kindness and sense of humour—one might almost say, of mischief—were a joy to those who knew him. He did not expect his men to do anything that he would not gladly have done himself and always considered himself *condemned* to go about in a Rolls-Royce car and sit in a comfortable chair.

The Battle for Superiority in the Air

At a time when the race for superiority in the Air was just beginning, and both sides were producing faster and better aircraft one after the other, Trenchard knew that success depended on the continued high morale of

The first Passing Out Parade at Cranwell on 23rd March 1920. H.R.H. Prince Albert, Duke of York (later King George VI) in the foreground with Air Commodore Longcroft, first Commandant, and immediately behind, Air Marshal Trenchard as he was then. On the left of the photograph, reading from left to right, are Wing Commander Sir Louis Greig, Air Commodore Ludlow Hewitt and Air Commodore Godman.

the pilots. In his view, " Improvements in mechanical science, to be of any use in war, depend on the skill and practice of those who use them."

His friend Haig, the great soldier, and Baring, the poet and diplomat, give us an insight into the character of the man himself. As a man of strong purpose he admired others like himself, whatever the sphere of their activities. That he was not a romantic but a true warrior is clearly borne out by his inherent belief in the spirit of the offensive in the air.

This was perhaps one of his greatest services to the Air Force. It was apparent in the early months of 1917 when, despite the high casualties which might well have struck at the very morale of the Service, he continued to maintain and foster this aggressive spirit in his pilots —a spirit which was the strength of the Royal Air Force in the last war, a spirit which has never died. Although there was much pressure upon him to turn to defence, attack was his policy for, as he had said in his memorandum of September 1916 on future policy in the Air, " The morale effect produced by one hostile aeroplane . . . is out of all proportion to the damage which it can inflict." Whether this is still true when one aircraft carrying one H-bomb can destroy a city is an interesting psychological study.

An increase in the German aggressiveness, which he anticipated at that time, would call for more and more protective patrols, but continued attack was his answer. The Germans did indeed pursue a more vigorous offensive and the struggle for air superiority became intense, centred around the personalities of Boelcke and Richthofen. Trenchard's doctrine of offensive air action leading to dominance has become the well-tried basic theory of air warfare, but in the First World War the newly found power of the air was scarcely fully tested: the swing of superiority vacillated between the two sides, coming to rest at last with us. Yet who was sure then that it must never be allowed to leave us? It was Sir Hugh Trenchard; and General Smuts stated that " for the winning of the war we should not only secure air predominance but secure it on a very large scale; and having secured it, in this War, we should make every effort and sacrifice to maintain it for the future. Air supremacy may in the long run become as important a factor in the defence of the Empire as sea supremacy."

The First C.A.S.

The programme of expansion that Trenchard advocated would have ensured immediate superiority for the R.F.C. in France had it been properly fulfilled, but it was subject to continual postponement and disappointment. It was not until 1918 that the R.F.C. felt the full benefit of these far-sighted schemes but, in January of that year, Trenchard was recalled from the Western Front to be the first Chief of the newly-created Air Staff. Sir Douglas Haig regretted his departure strongly, although he realised that such an appointment was in the best interests of the country. It was, in fact, the bond between these two men which nearly brought Trenchard's career to an abrupt end just as it was reaching its peak. After a disagreement with the Secretary of State for Air, Lord Rothermere, Trenchard was forced to resign for he preferred to stand by his loyalty to Haig rather than to play pawn in politics.

The Independent Air Force

Although the Air Force lost its new-found leader for a short time it was not deprived of his services. The

War had still to be won and in June 1918 he returned to command the Independent Air Force which was designed for the bombing of the German Homeland. As this new Force grew and became the Inter-Allied Independent Air Force, so a new horizon of air operations came into view.

This was the very genesis of strategic bombing; "As far as can at present be foreseen," said General Smuts in his report on Air Organisation of August 1917, "there is absolutely no limit to the scale of its (the Air Service's) future independent war use. And the day may not be far off when aerial operations with their devastation of enemy lands and destruction of industrial and populous countries on a vast scale may become the principal operations of war." Today the "deterrent" is based on that very fear of such destruction being wrought by the dreadful weapon at the disposal of the Air Forces of the World.

Master Builder of the Royal Air Force

It was one of those fortunate turns of Fate that Trenchard was induced to take up the reins as C.A.S. once again in April 1919 at a time when the very existence of the Air Force as a separate Service was at stake. It was then that the great work of building up the Regular Air Force began. Formed by the amalgamation of the Royal Flying Corps and the Royal Naval Air Service, the new force was practically a war creation on a temporary basis in which no count had been taken of the possibility of its becoming permanent. "The force may, in fact, be compared," said Sir Hugh Trenchard in his famous memorandum of 1919, "to the prophet Jonah's gourd. The necessities of war created it in a night but the economies of peace have to a large extent caused it to wither in a day, and we are now faced with the necessity of replacing it with a plant of deeper root. As in nature, however, decay fosters growth, and the new plant has a fruitful soil from which to spring." Our Air Force today and indeed the Air Forces of the world are founded squarely upon Lord Trenchard's memorandum; its provisions and far sighted policy for training and organisation are still the backbone of Air Power.

Training was the first need of the new Force and he saw that a fine regular cadre of officers and men was essential so that expansion in time of war could be quickly accomplished and yet provide a well balanced Air Force of ability. One of the ways of providing this cadre was effective schools. The Cadet College at Cranwell was opened in 1920, followed by the School for Apprentices at Halton and the Staff College at Andover. These establishments still give us the necessary material with which our strength is maintained, although the venue for the Staff College has moved from Andover to Bracknell.

But in addition to training, research is an essential ingredient if an Air Force is to be efficient on a long-term basis. This Trenchard fully realised and the arrangements he made were destined to produce the four-engined bomber, the high-speed fighter and radar, all of which when combined with crews of great quality, brought this country to victory in the Second World War.

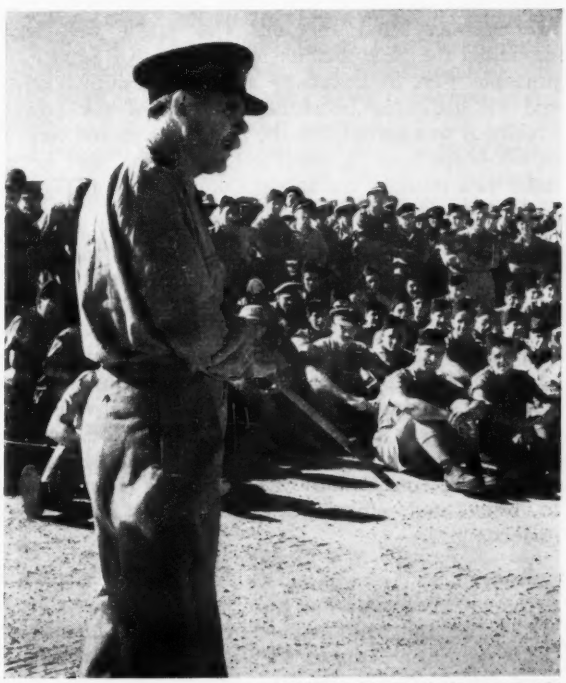
Peacetime Role of the R.A.F.

This organisation, however, was not enough; the R.A.F. had to establish itself in a peacetime role. Mr. Winston Churchill, who with Trenchard had seen the unmistakable evidence of the power of air control in Somaliland in 1919 when he was Secretary for War and Air, was faced with continual demands for the reduction of the enormous expenditure required for the control of the Mandated Territories in the Middle East, which had been put under our administration after the war.

Great difficulties were being experienced with the control of unruly tribesmen in these Territories: this was particularly so in Iraq, where in 1920 a general uprising broke out. In one year alone 92 Units of British and Indian troops and four Air Force squadrons costing many millions of pounds were needed to maintain order.

The Cairo Conference of 1921 under the chairmanship of Churchill, who had just become Colonial Secretary, accepted the "control without occupation" of Iraq, which eight squadrons of the Air Force could maintain at a fraction of the cost and with a total of only 12 Army Units. The outcome of the Conference was that an Air Officer Commanding was appointed to command the British Forces in Iraq.

This "air control" is still a task of the Royal Air Force in peacetime; today we have this important role to fulfil in Aden.



Air Ministry photograph, Crown copyright

Marshal of the Royal Air Force Lord Trenchard with the Air Force in the Western Desert on 17th October 1942.

Sir Samuel Hoare

So was the Royal Air Force established in the face of opposition and at this time—in 1922—another name, famous in Air history, arose to work side by side with Trenchard over seven hard years—Sir Samuel Hoare, the newly appointed Secretary of State for Air. He took over, however, despite the warning of the Prime Minister that the job might only last for a few weeks. Viscount Templewood, as he later became, has paid the greatest tribute to Lord Trenchard; he has called him the "Prophet" and given to himself the position of "Interpreter."

It is perhaps strange that two such modest men as Hoare and Trenchard should have made so admirable a team, anvil and hammer, to create and beat out a weapon whose edge has not blunted but rather grown more keen over the years—a weapon which, when put to the test for the first time when the very existence of this country was threatened in 1940, withstood the heaviest battering any Air Force had ever known and yet fought on to win.

The Naval Controversy

An earlier battle, not in war but yet of great significance in the days of the struggle for the unity of the Air Force, was the battle for the control of naval flying. The Royal Navy wished to have control of all that was on, or over, the sea but to the new Air Force such a division of responsibilities would have been a death blow. Beatty, the powerful, the persuasive speaker, the most popular of naval leaders, seemed an impossible opponent for Trenchard, the slow speaker, the gentle man. And yet, one by one, men of naval background like Salisbury and Balfour, who might well have supported the Navy's claim for a naval Air Service on principle, were impressed by Trenchard's sheer honesty and his dedicated belief in the unity of Air power. Finally, it was agreed that the Air Force should control carrier-borne aircraft, the Fleet Air Arm: that lasted until, as a result of the Inskip Committee in 1937, they reverted to the Navy again.

Inter-Service Liaison

The difficulties of liaison between the three Services were well known to Trenchard and the now well-established Chiefs of Staff Committee was his answer to the problem of co-ordinating Navy, Army and Air Force to produce joint briefs for the Government. However, it was not only in the highest places that he found prejudices between the three Services and the Imperial Defence College was founded at his suggestion to bring staff officers of the Services into closer understanding.

Early Struggles

The Salisbury Committee of 1923 had re-affirmed the R.A.F. as a permanent and separate Service and its recommendations as to the size of the Force gave Trenchard and Sir Samuel Hoare the task of building up the 52 squadrons that it required for home defence

Air Ministry photograph, Crown copyright

A particularly good photograph of Lord Trenchard taken at the S.B.A.C. Display in 1950 with Air Chief Marshal Sir Hugh Lloyd.

and of reviving the organisation which had been in a state of suspended animation since the end of the War. With the "Ten Year Rule"—which postulated each successive year that there would be no war for the next ten years at least—it was not an easy task. While Hoare fought for the money, Trenchard worked to put his ideas, already expressed in his memorandum of 1919, into effect. He had emphasised the extreme importance of training and also of research. His plan was, for the Secretary of State, a guide and "the irrefutable evidence of Trenchard's vision."

Doubts and difficulties lay in all directions around the R.A.F. in the 1920s, mainly, perhaps, because the basic tenet of Trenchard's faith—the power of independent offensive air action—was unproved, but also because the Air Force was not in a position of equality with the other two Services. It lacked the maturity which promotes tradition.

Such tradition had to be fostered in the new Service and, little by little, through the fight for a distinctive uniform and its own rank titles, the Royal Air Force emerged—"The debutant Service," as Sir Samuel Hoare called it. It had not been presented to the social world and that presentation was, strange as it may seem, an essential prerequisite to their acceptance as a fully-fashioned Force. Slowly but surely it became respectable!

Creation of "esprit de corps" was undoubtedly a problem, when both officers and men had to move constantly from Unit to Unit and where there was not the continuity of background of the Army regiments. Nevertheless, by dint of careful selection of commanding officers, by such simple things as distinctive markings

on the aircraft of operational squadrons and the granting of heraldic squadron badges, by healthy inter-squadron competition in the air and on the sports field, a truly remarkable "esprit d'escadrille" was created. But above all, in that tiny Air Force of the twenties of some 30,000 souls, there was apparent an almost evangelical spirit among the young men who, under Trenchard's inspiring leadership, were inflexibly convinced of the supreme importance of air power in the war which they knew in their hearts would one day burst upon them. They realised that only a fully independent Royal Air Force would be ready, with the right equipment and organisation—and with the right people in charge—and they were fanatically, although never blindly, devoted to the cause of its survival. Trenchard had no shortage of young men of calibre from Cranwell and elsewhere to take their appointed places beside the veterans of the Great War, each and every one a dedicated apostle of air power. So the superlative nucleus of the Regular Air Force was created.

The Reserves

But Trenchard well knew that his handful of expert professional airmen would be far too few to carry out the tasks which he knew his Air Force would one day be called upon to perform. One of the answers which Trenchard found was the Auxiliary Air Force which he planned as an élite company of adventurous young men rather like the old mounted yeomanry of his younger days. Whereas with the yeomanry the connection had been territorial, by counties, with the Auxiliary Air Force it was to be linked with industrial towns and cities like London and Nottingham, Manchester and Birmingham. They were to have fine Headquarters and plenty of social life and provide trained squadrons for the R.A.F. in time of need. They were to have, and did build, a tradition which was all their own—a fine tradition which, like that of the Regular Air Force, stood the decisive test of war.

In the Universities, too, Trenchard planned squadrons for basic training in aviation in a non-military way, which brought the right men to a consciousness of the great future in the Air.

In fact, the country slowly began to realise that air power and the Royal Air Force were here to stay. The prejudices were broken one by one. Trenchard was the prophet, planner, and, although he hated being called it, the "father" of the Royal Air Force. At least, then, let us call him the first Officer—his number was the first, 01001. In 1927, he became the first Marshal of the Royal Air Force and, with that promotion, the Air Force itself was promoted into definite equality with the Royal Navy and the Army.

The Beginnings of Air Transport

Concrete evidence of the worth of the R.A.F. had always been Trenchard's difficulty; he had little in the early days and his faith was not always enough to convince the doubters but, as time passed, the proof was forthcoming.

Two events during his period as C.A.S. gave, perhaps, the biggest fillip to the Air Force. Neither were in the field of war but in the realm of transport—air transport, then an entirely new concept.

The first of these was, strangely enough, the General Strike of 1926 during which the Air Force once again came to Churchill's aid, this time by distributing the "British Gazette" throughout the country. This really brought the Air Force closer to the people than it had ever been before. The other incident was one which fired the public imagination—the evacuation of the British Mission in Kabul between December 1928 and February 1929. This was the first air rescue operation ever flown by the R.A.F. and the lesson of the great importance of Air Transport was learnt then and has never been forgotten. I do not mean to give Trenchard all the credit for this particular episode for, in fact, it was Geoffrey Salmond, Air Officer Commanding India, whose imaginative mind had evolved the plan and his aircraft which did the work, but it was Trenchard's Air Force which could jump at such opportunities.

Meanwhile, within the Air Force itself Trenchard went everywhere, saw everything and everybody—especially the latter. His insistence on high morale was the very basis of his power in the Service, that and his unswerving demand for the greatest quality in all things.

Commissioner of the Metropolitan Police

On 1st January 1930, he relinquished his appointment as Chief of the Air Staff, after eleven long years, but was soon back at work again, this time as Commissioner of the Metropolitan Police—an arduous and responsible position which he filled for four years and to which he brought all his vigour and enthusiasm for organisation. The Police College and the Forensic Laboratories were among his innovations, together with many steps to assure the better living conditions of the Force.

I have no doubt that you all know the story which he was so fond of telling about himself. During the last War he was being driven along the Embankment to his office when he was forced to leave his car. He walked up Savoy Hill into the Strand where he found a policeman standing by a large roped-off area of the road. Since his way lay across the barrier, he typically went through it and continued to cross the road until he was stopped by a police Sergeant who admonished him for walking over an unexploded bomb.

"Why on earth didn't that constable warn me then?" stormed Trenchard. "Perhaps he recognised you, Sir," was the Sergeant's answer.

Conclusion

Time does not permit me to deal with Lord Trenchard's many activities during and since the Second World War but he continued to take a great interest in everything that mattered, especially the Royal Air Force, to the very end of his life.

He died on the 10th February, 1956, and his remains were laid to rest in Westminster Abbey in the presence of a distinguished company gathered together to do

honour to a great man—a man whose foresight, determination, and singleness of purpose forged the weapon which saved this country from defeat in 1940, and made victory possible five years later.

SIR GEORGE EDWARDS: Thank you Sir for a most memorable and moving address. It is not the custom on the occasion of first memorial lectures to have a discussion, but with us this evening is the Commissioner of the Metropolitan Police, Sir John Nott-Bower, and I will ask him if he would say a few words about Lord Trenchard.

SIR JOHN NOTT-BOWER, K.C.V.O.: It is indeed a great pleasure to be asked to pay tribute to Lord Trenchard.

Lord Trenchard was a great Commissioner of Police. He only filled this office for a comparatively short period of time, four years, but achieved an enormous programme of improvements and modernisation of the Force. Much of what he did was highly controversial, some of it unpopular with the Force: it is largely about those controversial things that the public heard so much. Little was heard of his immense achievements in regard to the housing and the welfare of the Police and in raising their operational efficiency in many directions. The effects of all this have been of lasting benefit. He was a source of constant inspiration to all who came in contact with him, and I count myself very fortunate to have been privileged to serve under him.

MAJOR G. P. BULMAN, C.B.E., B.SC., F.R.AE.S. (*Hon. Treasurer, Royal Aeronautical Society*): The C.A.S. in beginning his lecture referred to the well nigh impossibility of dealing adequately with the personality and career of such a great man as Lord Trenchard in a brief talk. Such a task calls indeed for the combination of an artist, a poet, and an orator. You will agree, I think, that Sir Dermot has in fact in himself provided such a combination this evening.

My own qualifications for the important duty I am now called on to perform are slender enough. It is true that I was myself commissioned in the Royal Flying Corps early in 1915; and that I owe it personally to Lord Trenchard, then C.A.S., that in 1928 I was appointed to undertake some responsibility for aero-engine development which enabled me for many years subsequently to maintain a very close association with the Royal Air Force.

Sir Dermot has sought, most successfully, to paint with his own delightful humour a picture of Lord Trenchard as a man, his humanity, simplicity, modesty, and great understanding of his fellow man. He has brought out the facts of his professional career and the high-lights of the history of his continuing battle for the Royal Air Force as a background, rather than as the main picture itself.

May I interpolate a further illustration of the methods of this man. In 1916 or 1917 a new type of aircraft, the R.E.8, suffered many grievous accidents. There was something radically wrong somewhere in the tail. The morale of the Squadron in France first supplied with these aircraft had been reduced to a low level, a desperately low level. Lord Trenchard had himself flown up to this Squadron in one of these aeroplanes. He lunched in the mess, talked with the pilots about this and that, but with no reference whatever to the aircraft, and subsequently took off in the same machine to return to his Headquarters. The pilots, feeling that this "crate" was good enough for "Boom" himself to fly, thought "Well, then, it is good enough for us." Their morale was restored and a successful modification to the tail soon introduced.

Behind every great man one will always find, in my belief, a great wife. And so it was in this case. We are therefore particularly happy and honoured in the presence of Lady Trenchard who will, I believe, have found happiness in Sir Dermot's portrayal of her great husband and feel that he himself would have been happy in it too.

Those of my generation who were fortunate enough to live through those early Flying Corps and R.A.F. days felt the full impact of Lord Trenchard's tremendous personality. The impression of it on me was, and always will remain, profound. The radiance of his personality shone around us and caused our helmets to gleam in its great light. You, Sir Dermot, I feel have rekindled the torch and have handed on the memory of this great man to the young Royal Air Force sitting before us, among whom, maybe, there is a future C.A.S. and in that you will feel, I think, adequately rewarded for the task you have so admirably performed tonight in giving this first Lord Trenchard lecture.

Mr. President, I am privileged to attempt to convey the appreciation of this great audience of what we have heard and formally to propose a vote of thanks to Sir Dermot Boyle, whom History, I venture to believe, will come to regard as one of the most distinguished successors of the great first C.A.S.

SIR GEORGE EDWARDS: There is nothing I think that I can add to the words of Major Bulman, except perhaps to say that this Old Society of ours, born in 1866 and still going strong, has had over that time a great many associations with the Royal Air Force in a great many ways. Through the medium of the Branches in existence in Air Force stations and schools, such as this, there are great personal ties between many of us in the Society and the Royal Air Force. I believe tonight we have really been a part of one of the greatest things that this old Society has ever done. To be here and take part in the tribute that has been paid to this great man in the presence of a Lady who sustained him so much during his life and is doing so much to carry on since and, of her family.

I would, therefore, ask you now to signify your approval of a vote of thanks, which I openly propose like Major Bulman, to the Chief of Staff, and we thank you, Sir, for the time and trouble you have given to the preparation of this address and for its sincere and moving delivery.

Pyestock's Contribution to Propulsion*

by

HAYNE CONSTANT, C.B., C.B.E., F.R.S. F.R.Ae.S

(Director, National Gas Turbine Establishment)

Introduction

The first Sir Henry Royce Memorial Lecture described the work of a brilliant engineer, who was directly responsible for the design of a long series of great engines. As a contrast, I have been asked to tell you about the work, not of an individual, but of a team. A team, moreover, that has had no responsibility for the final product, but whose task has been that of attempting to clear the ground and make the engine designers' work less difficult.

The year 1957 has a certain significance in gas turbine history, in that it is the twentieth anniversary of several important early events. It was in March 1937 that the Engine Sub-Committee of the Aeronautical Research Committee discussed the internal combustion turbine and as a result recommended " that the Air Ministry should take up the question of the development of the internal combustion turbine as a matter of urgency and make all possible arrangements for its production at the earliest possible moment . . . "

In the same year the collaboration between the Royal Aircraft Establishment and Metropolitan-Vickers began: a collaboration involving the design, construction and testing of a number of machines, starting with a string of axial compressors, passing on to such engines as the F.2, the first British axial jet propulsion engine, and culminating in a line of development leading through the Beryl and the F.9 to the Armstrong-Siddeley Sapphire. 1937 also saw the layout of the first double-compound arrangement, a method of obtaining greater flexibility at high pressure ratio that we have advocated ever since. It can, I think, be claimed that 1937 saw the start of effective work on the axial form of jet engine[1].

From this start, right through to the present day, there has been a continuity of technical policy at Pyestock in spite of the changes in name and in organisation to which we have been subjected. The present traditions and outlook of the National Gas Turbine Establishment can be traced back through its predecessor, Power Jets (Research and Development) Ltd. to the Turbine Division of the Engine Department of the Royal Aircraft Establishment, and it is unrealistic to attempt to differentiate between the contributions of the present Establishment and its parent organisation.

It is because of this difficulty that I have taken as my theme the work of Pyestock rather than that of the National Gas Turbine Establishment.

I have found this a far from easy paper to prepare, due primarily to the field being so large and the time scale so long that the subject tends to degenerate into a list of items. Continuity is very troublesome. Another difficulty which often arises when one tries to review the past is that some pieces of work, while notable in themselves, fall rather flat because for one reason or another, no immediate and direct use is made of them. Nevertheless, a perfectly cooked fillet steak is an achievement, even if no-one eats it. And achievements of this sort have a virtue greater than mere virtuosity, for very frequently they are a stepping stone to greater things.

A good example of this is the work which we did in 1946 when we were the first in this country to study supersonic centrebody intakes and to explain the instability which we called surge and which later became known as " buzz "[2].

For reasons beyond our control this work was not followed up but I hope and believe that it formed a base from which the advance of later workers became possible.

The first laminated turbine rotor, which we tested in 1949, is in a slightly different category, in that if it is a stepping stone, the next step has yet to be taken.

I think that in trying to assess what has been done it is necessary to keep in mind what in fact we set out to do. Our main objective, and the principal reason for our existence, has always been that of assisting industry to develop better gas turbines. Before this objective could be translated into practical politics we had to be clear in our minds just what constituted a better gas turbine. We had to define our technical policy.

Right from the very beginning of our work there was one basic concept in our philosophy that conditioned our general thinking. This concept was the vital importance in engineering development of making a sufficiently concentrated effort on a small front to keep ahead of all competitors. In a country such as ours in which the effort available is limited, this implies getting off the fence as quickly as possible and deciding definitely between alternative possibilities rather than giving a little backing to each. This is not an easy policy to adopt; hedging requires far less thought. It is a dangerous policy, because if you back the wrong horse you have nothing else to turn to; but if your judgment is good it gives great advantages.

The first example of this attitude of mind was our decision just twenty years ago, to abandon the centrifugal compressor of which we had quite a lot of experience, and to concentrate entirely on the unproven axial type. This judgment was based mainly on the belief that it was inherently more efficient to carry out the diffusing process in a compressor in a series of small steps at low velocity, rather than in a single large supersonic jump. As I recall it, the advantage of

*The Second Sir Henry Royce Memorial Lecture, given at the Derby Branch of the Society on 4th November 1957.

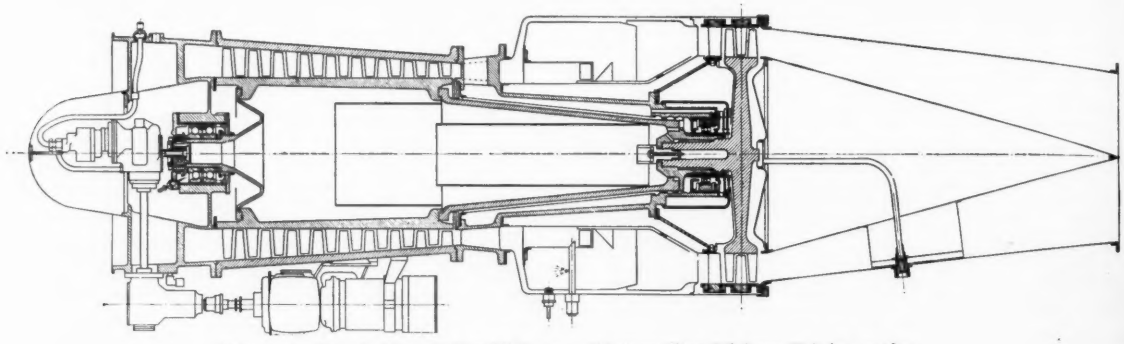


FIGURE 1. Royal Aircraft Establishment—Metropolitan-Vickers F.2 jet engine.

reduced frontal area was then regarded as secondary and that of lightness was not appreciated until some years later.

The next occasion on which we jumped off the fence was at the outbreak of war in September 1939. Up to then we had been backing the axial type of propeller turbine as opposed to Whittle's advocacy of the centrifugal jet. We climbed down, or rather climbed over, and backed the jet because we thought it an easier job than the propeller turbine and one which might be carried through in time to affect the war (Fig. 1). Having done this it was not long before we came to the conclusion that aircraft speeds were likely to continue rising in the future as they had done in the past and that therefore, sooner or later, the propeller would have to give way to the jet. And since in this country our resources were limited it would be better for us to take the final step right away, instead of first taking the intermediate and more difficult one of propeller propulsion. In spite of all that has happened in the intervening fifteen years I still believe that to be true. I think that if more attention had been paid to the jet and less to the propeller we should not now be so worried about the future of our air liners[3].

The axial engine lends itself to the annular type of combustion chamber, whereas the centrifugal engine favours the normal can type of chamber. Having plumped for the axial we naturally accepted also the corollary of using an annular chamber, and in fact specified it for, and assisted in applying it to, the Metropolitan-Vickers R.A.E. F.2 engine. We appreciated right from the start the advantages of the annular chamber in giving more flow area, and a more symmetrical air flow to the turbine, but years of frustration were needed to teach us the difficulties. However, we persevered and, after many ups and downs, we now believe that the annular chamber which we have been developing over the past year or two really represents a system which not only gets over the difficulties of distortion, stability and fuel distribution, which have so long been the bugbears of the annular chamber, but also represents a significant step forward in performance.

It was during the war (1942) that we first suggested the coaxial two-shaft compound engine as being the best method of achieving pressure ratios higher than could be attained in the simple engine. But it was not until after the war that we concluded that the double compound engine should actually be lighter than the simple engine, even at moderate pressure ratios.

Finally, we have steadily held to the view that our efforts should be devoted primarily to the aircraft engine and that the industrial and marine gas turbines would have to take second place. Of the many reasons behind this view perhaps the most practical one was that the aircraft engine industry was temperamentally and financially much readier to absorb new ideas and information and to convert these into practical progress.

In a word, then, we set out to help the aero-engine industry to make the best axial, compound jet engines in the world, and the great bulk of our efforts has been directed towards this objective.

We came to the conclusion in the very early days that the gas turbine lent itself to the study of problems on the component scale, and that most of gas turbine research could be done more effectively by working on components. Nearly all our efforts over the years have been directed towards the perfection of components, such as compressors and turbines, or even to sub-components, such as blade rows or even blades, and it is only recently that the problems of the complete engine have absorbed much of our attention.

From the start it was clear to us that the most critical component and the one most likely to hold back engine development was the compressor, and it was on this that we first concentrated our attention.

Compressors

In the early days, following the lead given by Dr. A. A. Griffith, a number of compressors had been designed relying on a combination of pure theory and divine inspiration. This seemed to work very well until we strayed into the region of compressibility, when one or other of the ingredients let us down. Fortunately we had at the same time been building up a stock of basic data on the performance of cascades of blades, and we quickly extended this to cover operation up to the speed of sound. This involved the first study to be made of compressor blades under choking conditions —a piece of work which we found fascinating and indeed exciting at the time—but which from a distance

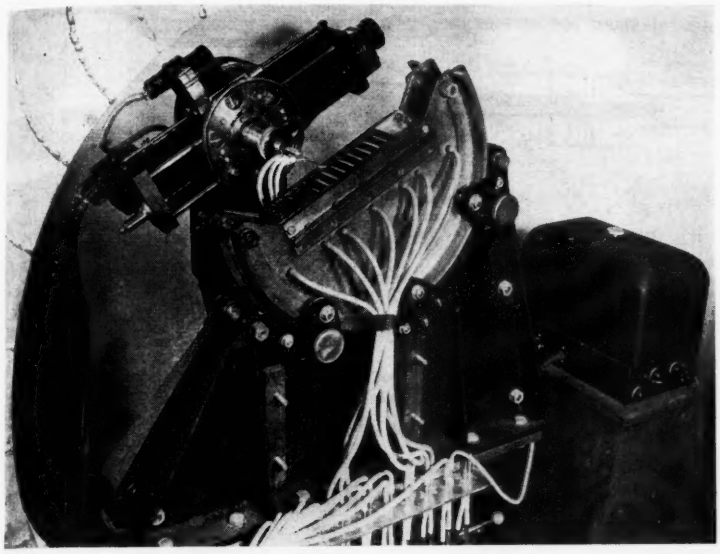


FIGURE 2. High speed cascade tunnel.

of fifteen years takes its proper place as a mere incident in the inexorable advance of knowledge. We learned quite early on the vital importance of the cascade test for providing the fundamental information on which all our compressor designs have come to be founded[4]. These measurements were actually made on three-dimensional cascades in a tunnel such as that shown in Fig. 2, but the results were corrected for end effects and could be regarded as basic data for blade rows.

After a little experience in correlating the measured performance of a limited number of compressors with the cascade data for the blade rows at mean diameter, a semi-rational theory to account for the behaviour of axial compressors was evolved. As more information gradually became available from tests on both compressors and cascades, this theory was refined and added to by a number of design rules, rules with which the name of Raymond Howell will always be associated. I think that the development of these design rules for predicting performance has been our principal contribution to the axial compressor[5].

These rules were based on a large number of tests of different kinds made on a variety of machines. They involved the analysis and interpretation by means of our general theory of compressor operation of the results of several hundred compressor tests made by industry and by the Establishment, Fig. 3.

In the course of this work detailed investigations have been made into a number of specific effects such as the nature of secondary flows, the effect of tip clearance and the influence of Reynolds number. The work on Reynolds number effects, which I think is of particular value, has been made possible by our possession of a special rig which we call No. 114. This is a return-circuit, variable density wind tunnel in which tests can be made over a one hundred-fold range of Reynolds number, Fig. 4. With this equipment the effects of density both on the aerodynamic and flutter performance of axial compressor stages have been studied.

The history of the aerodynamic effects has been slightly unusual in that the answers have been obtained by successive approximations. Over the years we have obtained, or been presented with, various data alleged to represent Reynolds number effects, with most of which we have been more or less dissatisfied. It was not until we had developed the 114 plant that we were able to get sufficiently controlled conditions and accurate results to make us believe that we had at last obtained a correct answer, Fig. 5. The flutter investigation showed that a reduction in the air density tended to move the blade away from the flutter region and therefore, in general, to reduce the vibrational stress.

Although great assistance has been given to our analytical work by testing other peoples' compressors, we have, from time to time, found a need for a more

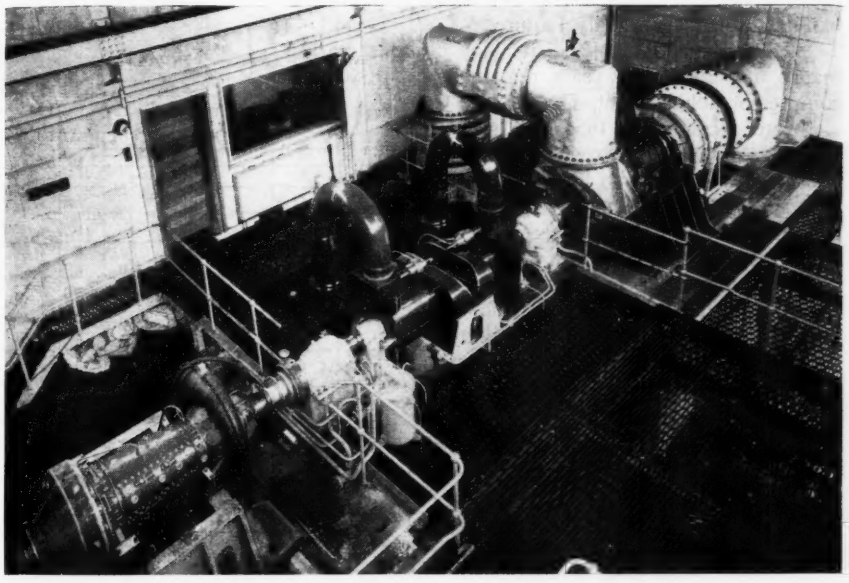


FIGURE 3. N.G.T.E. compressor test plant.

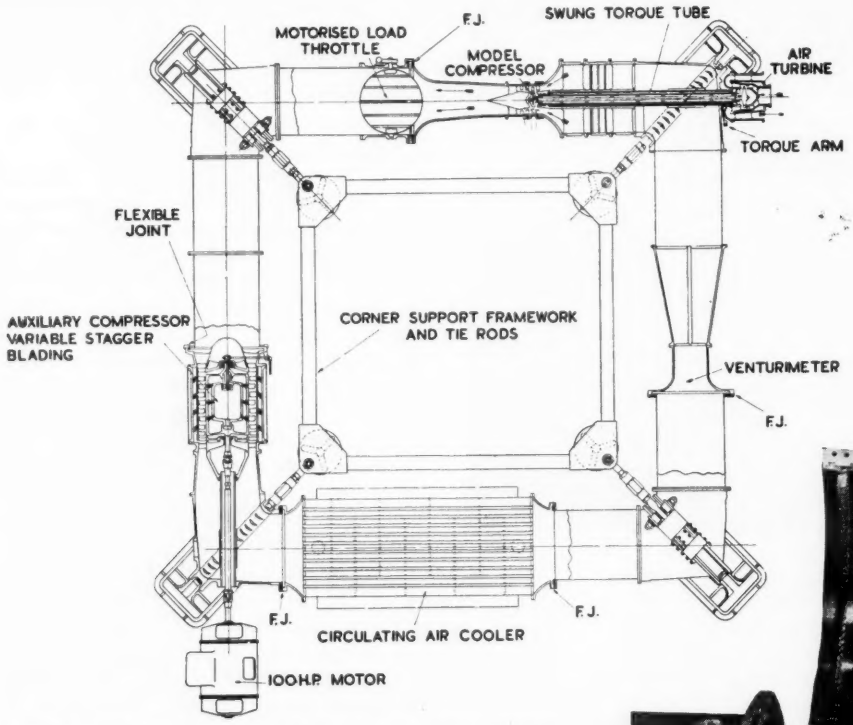
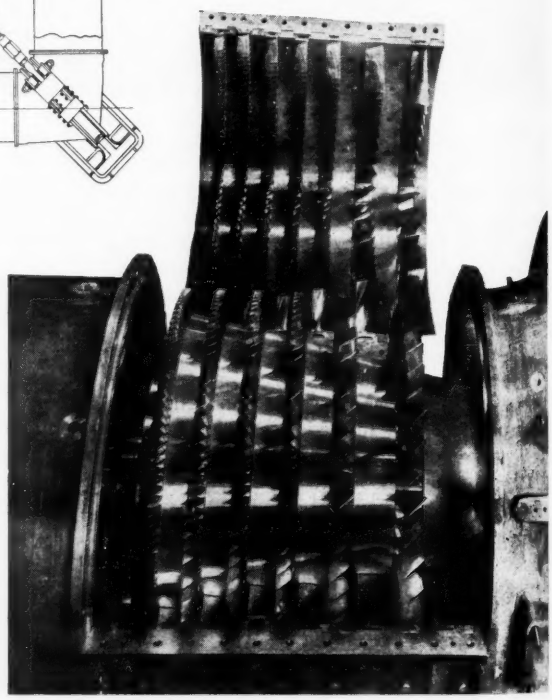


FIGURE 4. The 114 variable density test rig.

FIGURE 6 (*below*). The 109 compressor, 1946.



specific check on some detail point than these usually afford. In these circumstances we usually construct and test a compressor of our own design. A good example of such a compressor is our number 109 which we first tested in 1946, Fig. 6. Our general theory of compressor design had suggested that it should be possible by maintaining a high Mach number throughout the compressor and using blade details rather unusual at that time, to reduce considerably the number of stages necessary to obtain a required pressure ratio. Accordingly, this compressor was laid out to give a pressure ratio of nearly five to one in six stages, about half the number normally required[6].

The compressor achieved its high designed performance and for many years remained a milestone in compressor achievement, Fig. 7.

More recently, in 1956, the same compressor has been used to check another design point on blade profiles. Our general practice had been to use the same blade profiles throughout the compressor, but we had been gradually collecting data from our cascade tests that suggested that an improvement in performance would be obtained by varying the profile. It appeared that blading with a parabolic profile with its larger throat area passed a greater air flow, but with some loss in efficiency

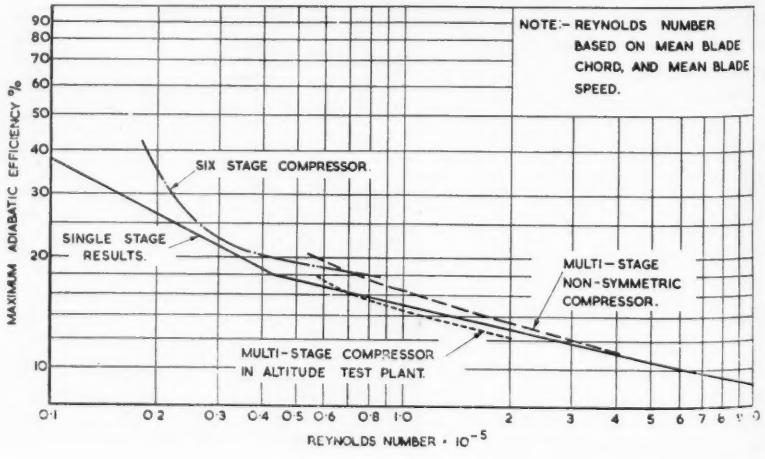

NOTE:- REYNOLDS NUMBER BASED ON MEAN BLADE CHORD, AND MEAN BLADE SPEED.
SIX STAGE COMPRESSOR.
SINGLE STAGE RESULTS.
MULTI-STAGE NON-SYMMETRIC COMPRESSOR.
MULTI-STAGE COMPRESSOR IN ALTITUDE TEST PLANT.
MAXIMUM ADIABATIC EFFICIENCY %
REYNOLDS NUMBER · 10⁻⁵

FIGURE 5. Reynolds number effects in compressors.

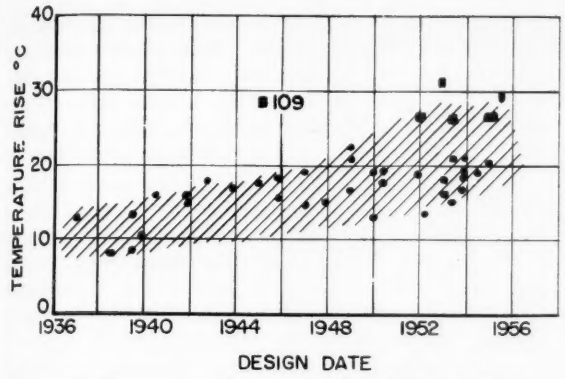


FIGURE 7. Temperature rise per stage in axial compressors.

at high speed, while blading of circular arc profile gave a higher efficiency at a lower flow. We therefore rebladed the 109 compressor, which originally had parabolic blading throughout, with blades changing progressively from circular arc in the first stage to parabolic in the last. A considerable improvement in the part load performance, with an increase in efficiency and a straightening of the surge line "kink" resulted, Fig. 8.

Turbines

In gas turbine research there has always been an unusual degree of co-operation and exchange of information. Individual contacts and formal organisations, such as the sub-committees of the Gas Turbine Collaboration Committee, have sometimes resulted in such close relations between different bodies working on the same problem as to give the impression that the work was being done by a single unit. The evolution of the aerodynamic design of turbines is a good example.

In the early designs of turbine the highest possible loading per stage was aimed at, the limit being set by the avoidance of recompression at the blade root. It was not until near the end of the war that it was realised that turbine efficiencies were lower than had been expected, and were mainly responsible for the poor engine specific fuel consumptions of that time.

Immediately after the war we carried out the first tests on the turbine components of gas turbine engines[7], in this country, and backed them up by a comprehensive range of cascade testing, Fig. 9. As a result of this work we came to the conclusion that the principal cause of poor efficiency in contemporary turbines was their high aerodynamic loading, and we pressed for the development of multi-stage turbines[8]. By 1950 the blade loading parameter for stages without exhaust swirl, $k_p\Delta T/\frac{1}{2}U^2$, which had previously risen to over 4·0, had dropped to between 2·5 and 3·0, and substantial gains in efficiency had resulted, Fig. 10.

The importance of a high degree of reaction had been appreciated from steam turbine experience. Others had demonstrated the gains resulting from a reduction in blade clearance and flow leakage. It remained for the Establishment to analyse the combined experience of many and produce in 1951 a systematic method for predicting overall turbine performance[9,10].

Cooling

The turbine provided us with another kind of problem when it became clear that it would need to be cooled to make possible the use of a really high gas temperature.

It is often the case when one wishes to achieve something, that the gaps in one's knowledge and the problems to be solved are apparent, and a process of research and development can be set in train that will ultimately achieve the desired goal. But occasionally the difficulties are not all quite so clear, and then it is usually best to "have a bash at it," and let the difficulties speak for themselves. The work which we have done on the cooled turbine is an example of this. When we decided in 1946 to clear away the problems which required solution before a cooled turbine could be run, we found ourselves in some doubt as to just what the

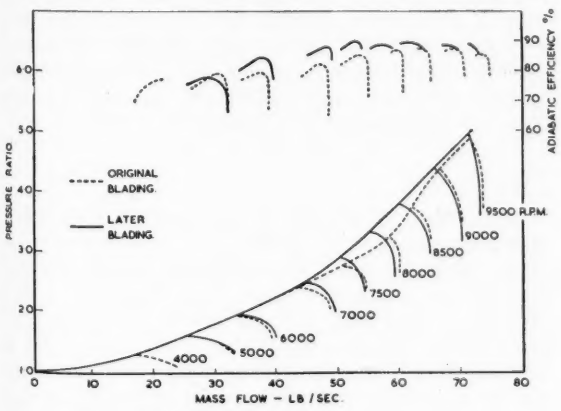


FIGURE 8. Performance of 109 compressor.

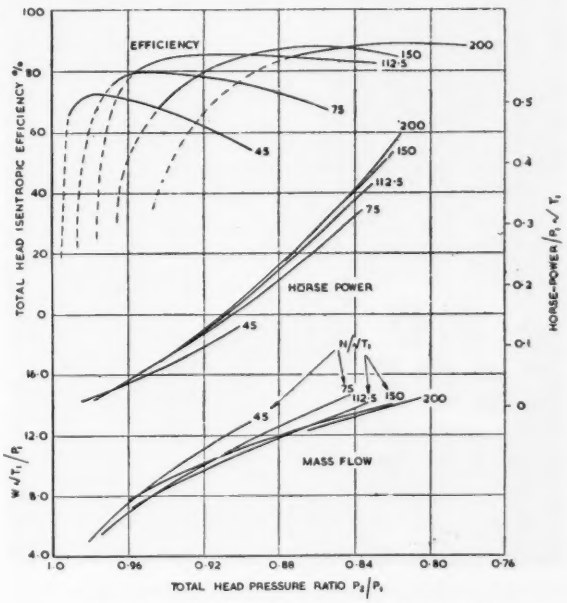


FIGURE 9. Characteristics of first turbine tested.

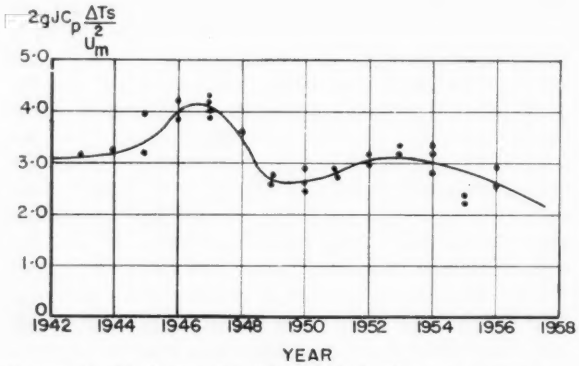


FIGURE 10. Variation of turbine blade loading parameter over the years.

problems were. What was the real difficulty? Was it the cooling of the blades or the large areas of stationary ducting? The answer seems obvious now, but for quite a time it seemed to us that the cooling of the ducting without excessive loss was going to prove far more difficult than that of abstracting the much smaller quantity of heat from the blades. So far as the blades were concerned we were worried by the possibility that deposits of dust might block the cooling passages. It was also not at all clear whether it was better to use air or liquid cooling. If liquid were used, would the rotor become unbalanced by an unsymmetrical distribution of liquid? We were sure that we would need to know the transfer coefficients for heat flow into the blade and from the blade to the cooling medium, but that was all we were sure of. Accordingly we decided to make a cooled turbine and see what the real difficulties were. At the same time a cascade tunnel was built with cooled blades in order to get the information needed on heat flow into and out of the blade, Fig. 11.

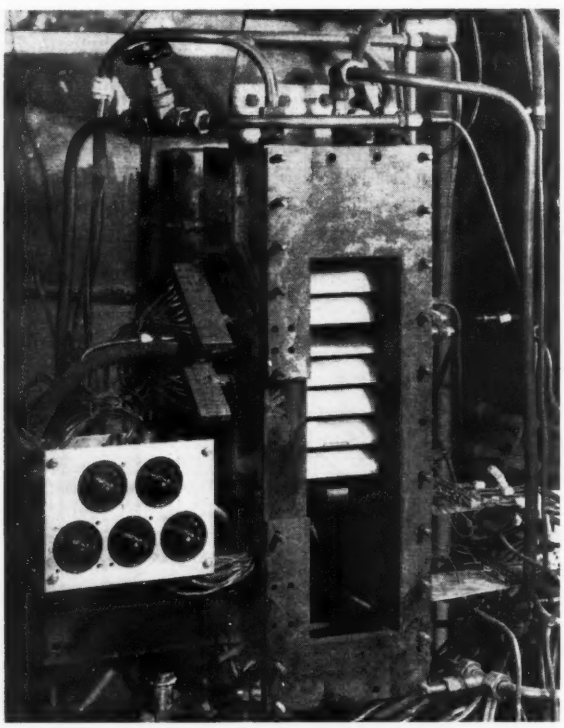


FIGURE 11. Hot turbine blade cascade tunnel for heat transfer data.

I have dwelt on the uncertainties in our minds eleven years ago to emphasise the thought which has occurred to me several times very forcibly in the course of preparing this paper—how simple problems are once they have been solved. The corollary to this is, of course, that there is little future in looking backwards.

After preliminary experiments with free convective cooling and liquid cooling using closed tubes the conclusion was reached that these methods were too difficult and that it might in fact be fundamentally wrong to bring the heat down into the rim of the rotor, where it was difficult to dispose of. We therefore decided that the first technique to try was one using air. The first tests on an air-cooled turbine were made in 1952 and the first runs with a mean gas temperature of over 1100°C, in 1953. Since then much further work has been done on turbines operating under a variety of conditions (Fig. 12), and at higher gas temperatures. In parallel with the experimental work on the cascade rig and the air-cooled turbine, a lot of analytical work was needed to build up a supporting theory. At the same time subsidiary tests were done on a water-cooled turbine and on one whose blades were cooled by a water spray, and novel methods of constructing cooled blades, such as the use of lost wax castings, were developed.

All this was real pioneering work carried out some years in advance of anyone else, work which I think has resulted in our gaining a reasonably exact understanding of the problems of turbine cooling[11, 12, 13].

While this work on the turbine was going on we spent some effort on the related problem of cooling the walls of ducts, such as the flame tubes of combustion chambers. A criterion of cooling effectiveness was developed and this was used to compare the relative efficiency of a number of different cooling systems. As a result of this work we suggested in 1950 that the best practical method of cooling a duct was by a series of films of air bleeding into the hot gas stream, fed from a chamber so jacketed as to give good convection cooling. We have successfully used this combination of external convection cooling and internal boundary layer or film cooling on a number of occasions.

Combustion

My only contribution to gas turbine combustion is confined to a brief period over twenty years ago at the Royal Aircraft Establishment during which I did my first combustion test. I arranged for a flow of air to emerge from a bit of six-inch piping at a few hundred feet per second. I then contrived a solid jet of diesel fuel from a small bore pipe. My fitter threw a piece of burning waste into the jet, thus lighting it. I then poked the burning jet into the six-inch pipe,

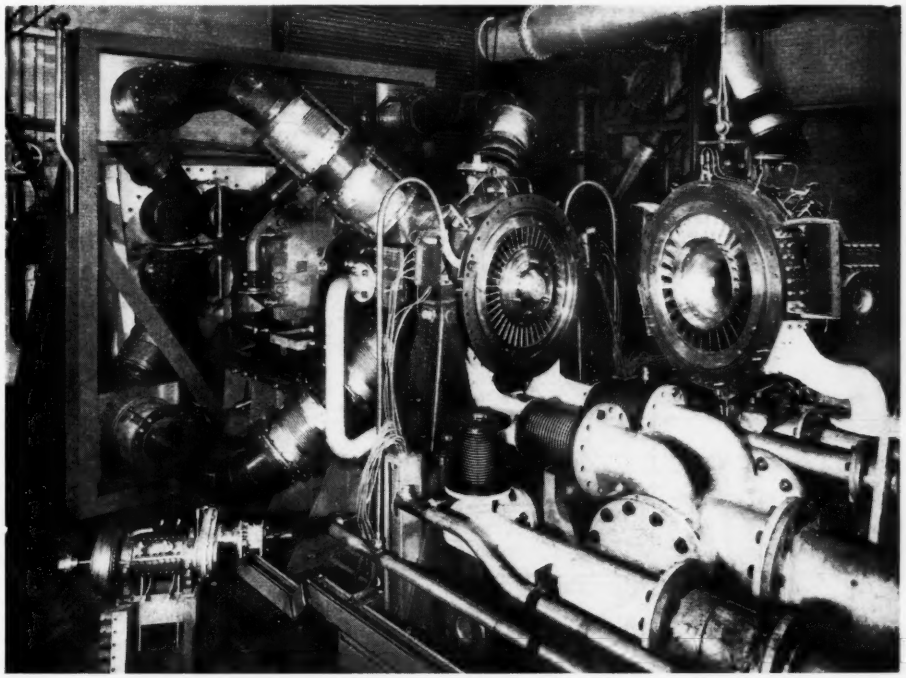


FIGURE 12. Air-cooled turbine test rig.

and the flame went out. This created a precedent. The object of the past two decades of work at Pyestock has been to improve on this state of affairs.

We set about this first of all by deprecating as far as possible the element of black magic in the design of combustion systems and by trying to put the combustion process on a quantitative basis. Various instruments and techniques of measurement—such as our gravimetric system of gas analysis—were developed and we tried to isolate in turn each of the many physical and chemical processes that normally occur together in a combustion chamber[14, 15, 16, 17].

Having effected such an isolation, or more usually, having simplified the system by eliminating a few of the variables, we have attempted to study the behaviour of the more elementary system.

As an example of this I may mention the work that has been done in defining the underlying principles controlling the burning of individual droplets of fuel.

A study was made of cold and hot evaporation of these droplets when hanging freely on fine silica filaments[18] and also when falling freely through a furnace. In a third technique a camphor sphere was mounted on a damped, counter-balanced, pendulum in a wind tunnel. These researches have led to a quantitative understanding of the laws governing the evaporation rates and lifetimes of hydro-carbon fuel droplets, and of the effects of Reynolds number on the drag of burning droplets.

The ignition delay of fuels injected into a hot gas stream was another isolated process on which effort was concentrated. The technique developed enabled measurements to be made within the time range one to thirty milliseconds of the ignition delays of different fuels, and showed up the influence of variables such as spray droplet size, static pressure, mixture ratio, fuel additives and the oxygen content of the air stream[19].

The filling in of basic data on elementary combustion processes such as these is gradually giving perspective and balance to the view of the combustion engineer and enabling him to make his judgments on a quantitative basis. A good example of this is the success that has attended our efforts to define precisely the effect of linear scale in combustion chambers[20]. Our early work gave the first effective analysis of the significance of linear scale in high speed combustion processes and showed how model tests could be used to simulate full scale performance. Later work by ourselves and others — notably Rolls-Royce — has extended our understanding by explaining the effects of fuel injection and heat transfer.

We have tried to avoid becoming too academic by continually applying to the design of practical chambers what insight we have been able to gain into the individual processes of combustion. This is a necessary discipline and one that in the combustion field leads to many promising hypotheses being stillborn. Of the considerable number of novel combustion chambers that we have worked on, I will mention only one by way of example. For some years we have been trying with some success to make more rapid progress in increasing the rate of heat release from a chamber. The most recent and most notable advance here has been a chamber having a heat release of 6×10^6 CHU/ft.^{3}/atm./hour, about three times that of current chambers, without a penalty being paid in other aspects of its performance.

This great compactness has been achieved by building into a single chamber four novel features, Fig. 13. The first of these is the elimination of the compressor diffuser, thus shortening the length of the chamber. The secondary air is led straight through the chamber at high velocity to a sandwich mixer, in the cool air passages of which lie the turbine nozzles. Mixing of secondary and primary air takes place in the nozzles, which are at the same time effectively cooled. Uniform peripheral distribution of fuel into the annular primary zone is effected by dispensing with the normal type of injectors and passing the fuel off the lip of a spinning disc. The turbulence in this primary zone

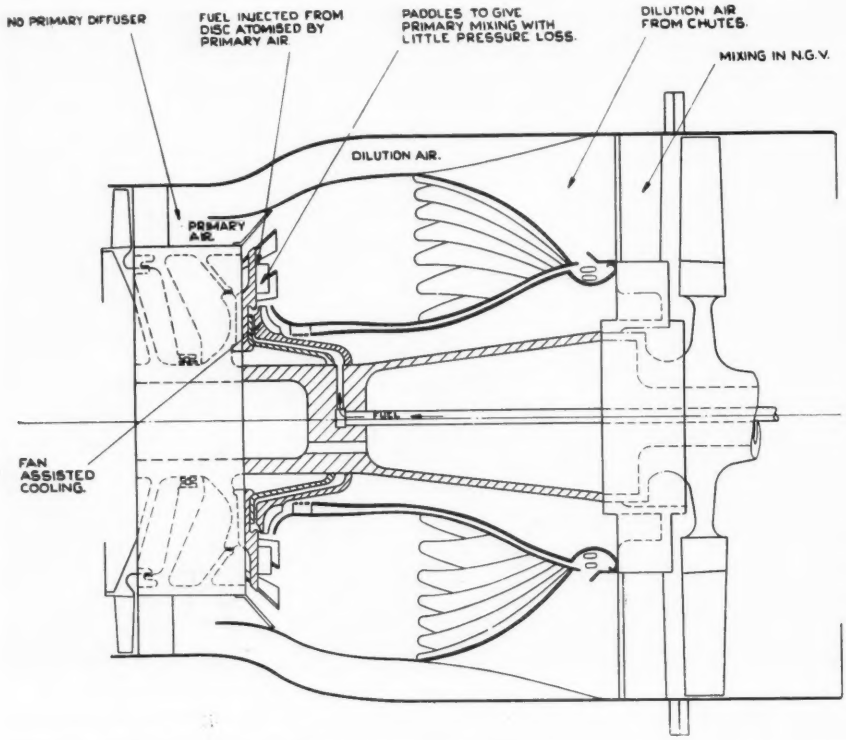


FIGURE 13. N.G.T.E. short combustion system.

and the strength of the stabilising vortex are increased by paddle wheels attached to this disc.

I think that this may prove to be a revolutionary step forward in combustion chamber design.

Reheat

Passing now from the main combustion chamber to the jet pipe, I will refer briefly to our work on reheat, or burning in the jet pipe as we used to call it. This started in 1943 with an attempt to check by experiment the theoretical prediction that increased thrust should result from burning fuel after the turbine and before the propelling nozzle.

The first experiments were done in an air supply simulating, as we thought, the conditions in the exhaust pipe of a jet engine. These experiments led to the conclusion that it would be possible to burn fuel in the exhaust in spite of the very high gas velocity. A Power Jets W.I.A. engine was then obtained and the first reheat combustion system was built into its exhaust pipe. The main feature of the system was the perforated pilot chamber formed as an extension of the exhaust bullet. Within this chamber were mounted a sparking plug for ignition and an upstream pilot jet. Downstream of the pilot chamber was a single main jet which directed a spray of fuel into the pilot chamber. The noise and flame produced by this elementary system gave a sense of power not completely confirmed by the readings of the spring balance. However, the results were sufficiently promising to justify going ahead with the development and attempting to make a system which was reliable and at the same time gave a reasonable increase in thrust.

Reheat was forced into the air before its time by the flying bomb attacks on London in 1944. Although these attacks were repulsed before reheat could be demonstrated in action, a significant improvement in aircraft performance was obtained. The aircraft used was a Meteor I, fitted first with Rolls-Royce Welland engines and later with Power Jets W.2/700s. With these last engines reheat gave a speed of 500 m.p.h., an increase of 46 m.p.h. over that achieved without reheat, Fig. 14.

The main thing that came out of the Meteor tests was the realisation of the limitation on performance imposed by the pressure in the exhaust system, it being found difficult to get reliable operation much above 30,000 ft. At roughly the same time it was realised that it would not be possible to spread the flame from a single central flame holder and that a multi-stabiliser system would be necessary if large increases in thrust were to be obtained. To overcome these two difficulties a fresh start was made in 1947 with a new combustion system borrowed from our ram-jet developments. In this system fuel was injected upstream from a number of jets placed in the exhaust diffuser. A number of conical stabilisers, each carrying ignition sparking plugs, held the flame in a plane some four feet downstream of the main jets. With this system and developments of it, a good performance over a wide range of conditions was obtained on W.2/700 engines. For example, when giving a 40 per cent increase in static thrust with an outlet temperature of about 1,500°C, the specific fuel consumption was 6·2 lb./hr./lb. In flight it was found that the system was capable of operating at exhaust pipe pressures equivalent to an altitude of about 49,000 ft. In the same system it was found that by staging the fuel supply to the separate jets a continuous variation of thrust boost from $2\frac{1}{2}$ per cent to 30 per cent could be obtained[21].

By 1951 it seemed to us that the back of the problem had been broken and that it would be reasonable for us to transfer our effort to other work, leaving the further development and application of reheat to Industry. (The application in this country has not, in fact, been as rapid as we had expected.)

Ram-jets

Although the work on our reheat system was

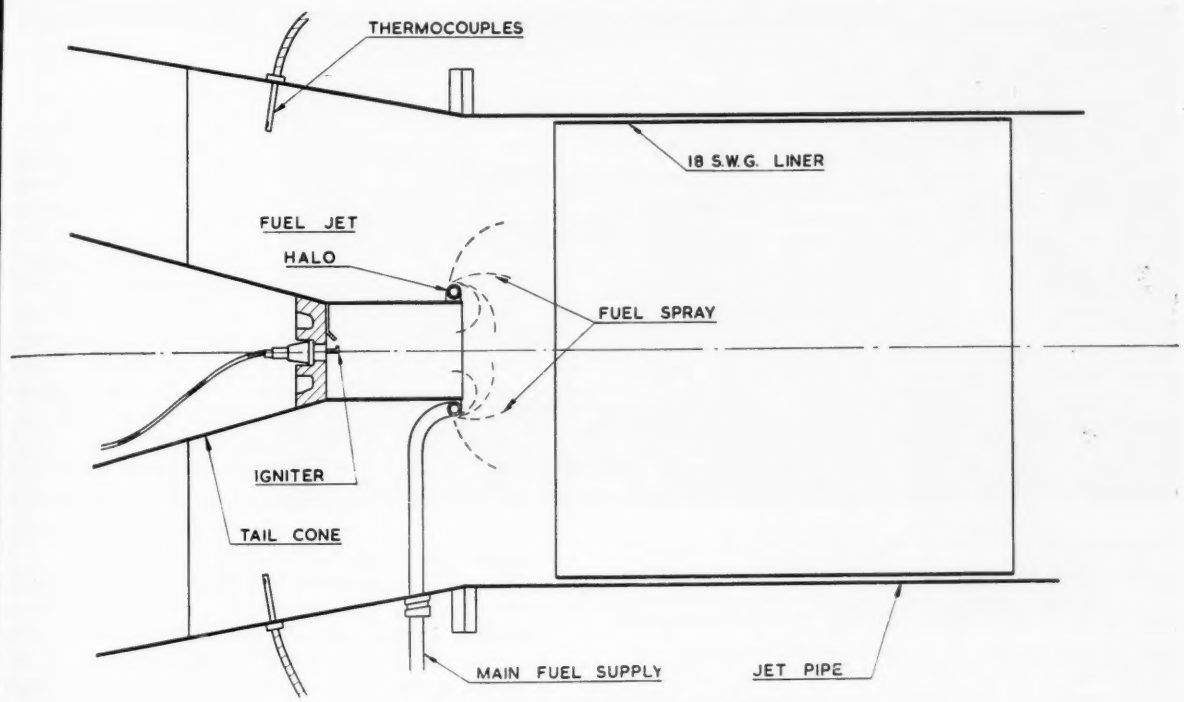


FIGURE 14. Reheat for Meteor aircraft 1945.

brought to an end some years ago, there has been no diminution of the effort we are putting into the allied project of ram-jet propulsion. We had begun work on devices of this kind—which we then called propulsive ducts—in the early days of the last war, and foresaw their future as thrust boosters in aircraft. In 1944 the first British ram-jet did its bench test at Pyestock and was flown in a Mustang aircraft in 1946. Although this first attempt was hardly a success, we produced in 1945 another design which actually achieved its design thrust. This little 7·2 inch diameter unit was, however, not large enough to give more than a demonstration of the possibilities of this form of propulsion. In 1950 ram-jet work was given over-riding priority at the Establishment and a properly instrumented unit of 16 inch diameter was started. The general objective which we set ourselves was to design, build, test and fly a missile type of ram-jet, to see what the problems and difficulties were, and to overcome them; at the same time collecting what basic data appeared necessary. We have, I think, succeeded in doing this and have demonstrated a ram-jet propulsion system operating with first-rate performance over a wide range of flight conditions up to a Mach number of 2·5 and 60,000 ft., Fig. 15.

In this ram-jet we have used for the first time a two-stage combustion system in which the cruise fuel injector acts as a pilot and is kept in continuous operation, the second stage injection being used only during take-off and climb. This idea is slowly becoming accepted as essential for a propulsion system which is required to give good performance over a very wide range of conditions.

We also demonstrated in this test vehicle the first internally-cooled jet pipe capable of operating at stoichiometric mixture strength.

Nozzles and Spoilers

The work which has been done on nozzles and spoilers is another example of our developing something either as a demonstration that it can be done, or in order to throw up the real research problems.

One of the earliest examples of such a demonstration was the development of a thrust spoiler in 1944, Fig. 16. This was the first device of its kind to be produced in this country, and possibly in the world. It worked quite well, first on a W.2B engine and later on a W.700. It was developed on the test bed and then flight tested in a Wellington flying test bed. We had originally intended to try it out next in the Supermarine Attacker, but doubts about the ability of the aircraft to withstand the buffeting which it was expected it would receive caused this plan to be dropped. By this time Industry had taken up the development of thrust spoilers and reversers and so we proceeded no further.

As a contrast to this, one of the most recent demonstrations of the Establishment may be mentioned. This is an attempt to solve the problem of the variable area propelling nozzle for ram-jets, capable of operating at stoichiometric mixture strength. It seemed to us that the most likely solution to this problem would be one based on the centre plug arrangement with axial movement, similar to that developed for the Jumo engine during the 1939-45 War. The main disadvantages of this arrangement are, firstly that in order to operate at the highest temperatures that can be developed by

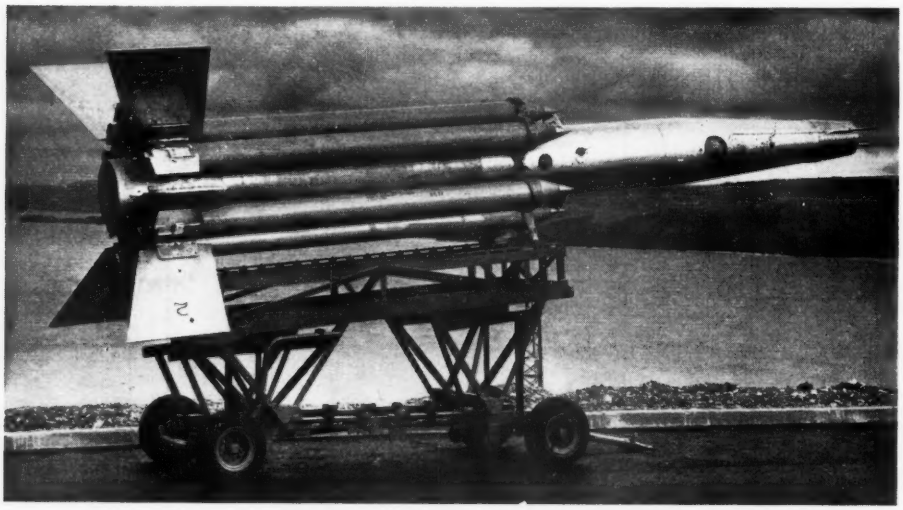


FIGURE 15. Ram-jet test vehicle.

hydrocarbon fuels it is desirable to avoid supports spanning the hot gas stream. This involves mounting the bullet on a long sting-like structure carried to a locating point upstream of the flame holders. The other disadvantage is that the ratio of minimum to maximum throat area is not as small as one would have liked.

A nozzle of this kind was designed and made last year for our 16 in. ram-jet engine, Fig. 17. It was constructed on flight scantlings with full allowance for acceleration loadings and weighed 90 lb. The stalk and plug are air-cooled and require about 4 per cent of the air throughout to maintain the surface temperature at a level of about 1,000°C. The nozzle has been tested at stoichiometric mixture strength giving a gas temperature of about 2,000°C with a pressure level of 47 p.s.i. absolute. The behaviour was good, vibration being small and the strip condition satisfactory.

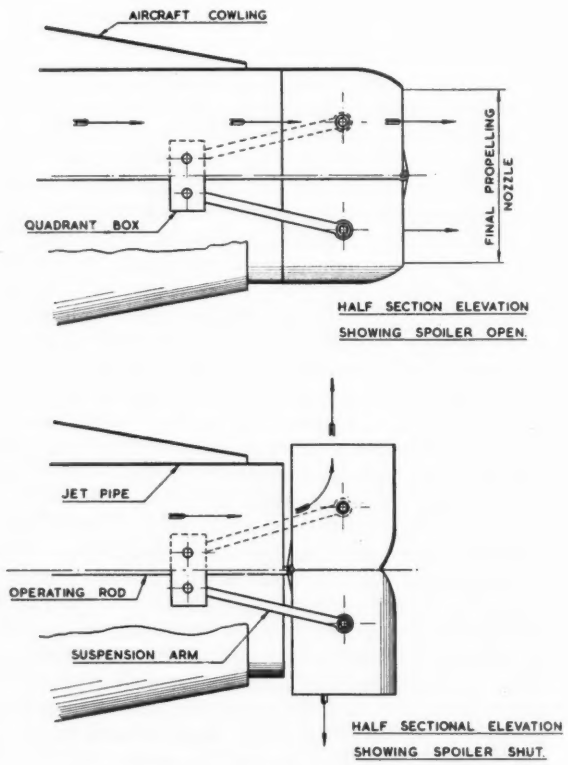


FIGURE 16. Thrust spoiler 1944.

Engine-Assisted Lift

Our first contribution to engine-assisted lift was the development of the switching boxes used in the jet deflection Meteor aircraft which flew in May 1954. This was the first occasion on which an aircraft flew with jet-assisted lift. More recently we put forward the suggestion that the engine exhaust should be emitted from the trailing edge of the wing in a thin sheet, and showed by wind tunnel tests what large increases in lift coefficient could thus be obtained, Fig. 18. This idea, called the jet flap, was of immediate interest to the aerodynamicist in providing a new approach to the concept of fluid flow past an aerofoil[22]. It is conceivable that it will prove to be the essential feature of a practical method of reducing landing speed.

Conclusion

In trying to sum all this up I think that it can be truly said that by exhortation and example we laid a foundation on which industry has constructed what are probably still the best axial jet engines in the world. This foundation has been made up of a number of different parts. There is first of all the development of various pieces of hardware that we have succeeded in making work before anyone else. I think that there has been merit in this if for no other reason than that it made clear that such things could be done.

Another important part of the foundation has been the production of basic data on the phenomena occurring in practically every part of the engine.

The great mass of routine tests that we have done on compressors, turbines, combustion chambers and other engine components for every gas turbine firm in the country are of less permanent value and can perhaps hardly be included in the foundation.

I have referred to a number of pieces of work which are characterised by some special feature that makes them significant, such as being first in the field.

But although these eye-catchers have their value, I suspect that our greatest contribution to aeronautical propulsion has been something rather less spectacular.

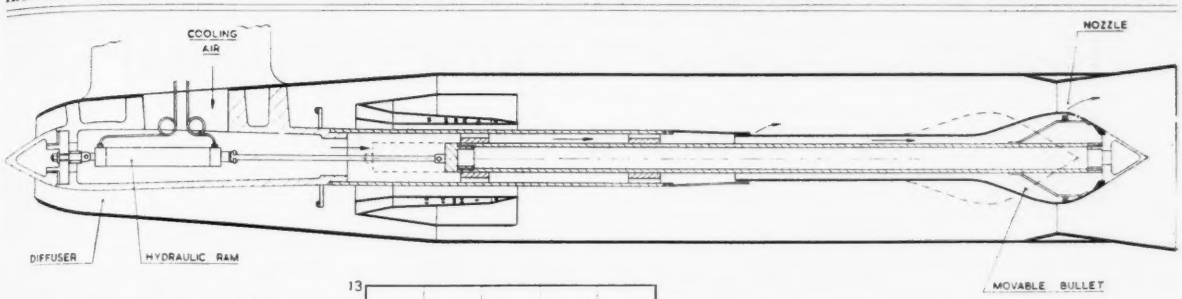


FIGURE 17. Cooled variable propelling nozzle, 1956.

I am referring to the large number of rather humdrum investigations that have been pursued over the years in very close contact with Industry and other research organisations; investigations on such diverse problems as the effect of intake disturbances on engine stability and the emissions of infra-red radiation from an exhaust system; work on blade flutter, on engine control, on electric tanks and non-dimensional methods for determining part load performance. We have played our part and made our contribution to a very long list of items of this kind—the raw material of technical progress. Much of this work has been mere drudgery. Progress has been so slow that it is only by looking a long way back that one can see how far we have all come. In this kind of work interchange of information has usually been so complete that it has often been difficult to say from where each new idea came and to whom the chief credit was due.

This has been true co-operative research and I am glad that so much of our work has been of this kind. I suspect that the future will need even closer collaboration.

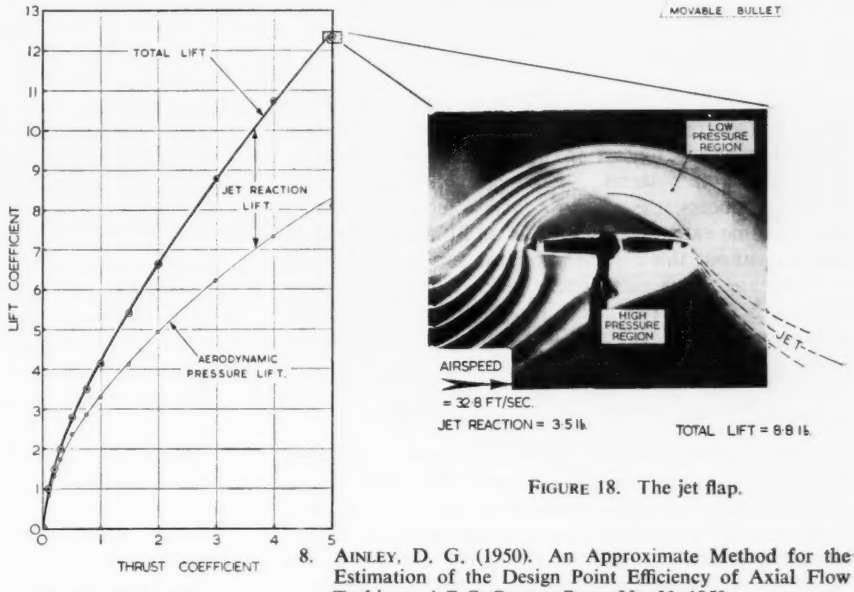


FIGURE 18. The jet flap.

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Flow Visualisation Techniques Applied to Combustion Problems

by

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1. Introduction

Workers in the field of continuous combustion have long been aware of the importance of the part played by the aerodynamic factors in the satisfactory operation of combustion systems. Although only part of a complex process, the air flow in a combustion system can, to some extent, be studied as an isolated individual factor, without the complications of fuel injection and heat release. This may appear to involve a rather long step from reality, but observations of the basic "cold" flow conditions in such a system can provide a valuable basis for the prediction of the effects of variations in the equipment, particularly in systems conforming to a particular type.

The similarity between "hot" and "cold" conditions must clearly not be presumed beyond reasonable limits, and the extent to which quantitative data on the basic flow pattern can be applied to combustion conditions depends very much on the characteristics of the system being studied. Investigations at Thornton, some of which have been reported elsewhere[1], have shown that in certain types of system the "hot" and "cold" flow patterns agree closely, except for the accelerations due to heat release, and that quantitative observations made in the absence of combustion can then be utilised for the determination of approximate values for the burning condition. Fig. 1, for example, demonstrates the similarity between the actual flow patterns in a particular system with and without combustion.

For the study of cold flow patterns, the author and his colleagues have found that the method of direct flow visualisation through transparent models, in which water takes the place of air, offers considerable advantages over other methods of determining the flow details. The reasons for the preference of the water visualisation technique have already been stated[2] and can be summarised as follows:—

(*i*) Direct visualisation allows the simultaneous observation of the whole flow field in minute detail, without obstruction by instruments, and permits the immediate qualitative assessment of the observation without the need for computation of traverse readings.

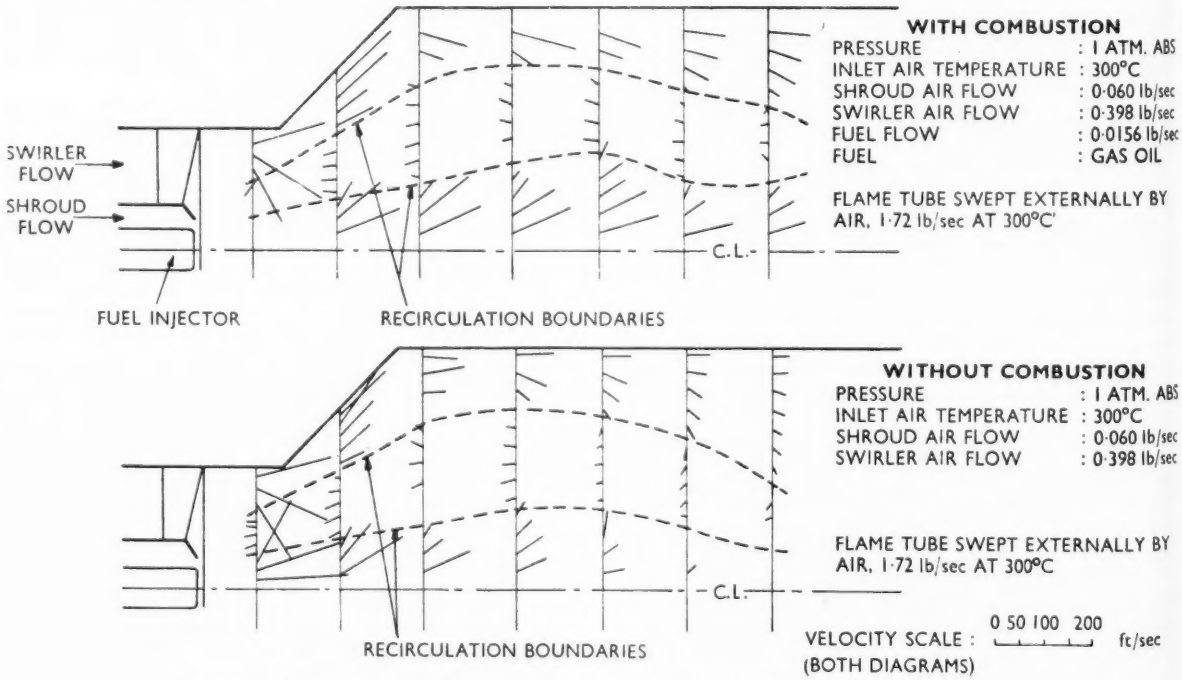

WITH COMBUSTION
PRESSURE : 1 ATM. ABS
INLET AIR TEMPERATURE : 300°C
SHROUD AIR FLOW : 0·060 lb/sec
SWIRLER AIR FLOW : 0·398 lb/sec
FUEL FLOW : 0·0156 lb/sec
FUEL : GAS OIL
FLAME TUBE SWEPT EXTERNALLY BY AIR, 1·72 lb/sec AT 300°C
SWIRLER FLOW
SHROUD FLOW
C.L.
FUEL INJECTOR
RECIRCULATION BOUNDARIES
WITHOUT COMBUSTION
PRESSURE : 1 ATM. ABS
INLET AIR TEMPERATURE : 300°C
SHROUD AIR FLOW : 0·060 lb/sec
SWIRLER AIR FLOW : 0·398 lb/sec
FLAME TUBE SWEPT EXTERNALLY BY AIR, 1·72 lb/sec AT 300°C
C.L.
RECIRCULATION BOUNDARIES
VELOCITY SCALE : 0 50 100 200 ft/sec
(BOTH DIAGRAMS)

FIGURE 1. Results of radial probe traverses in the combustion zone of a gas-turbine system, with and without combustion. The vectors refer to components in the central plane; swirl components are not shown.

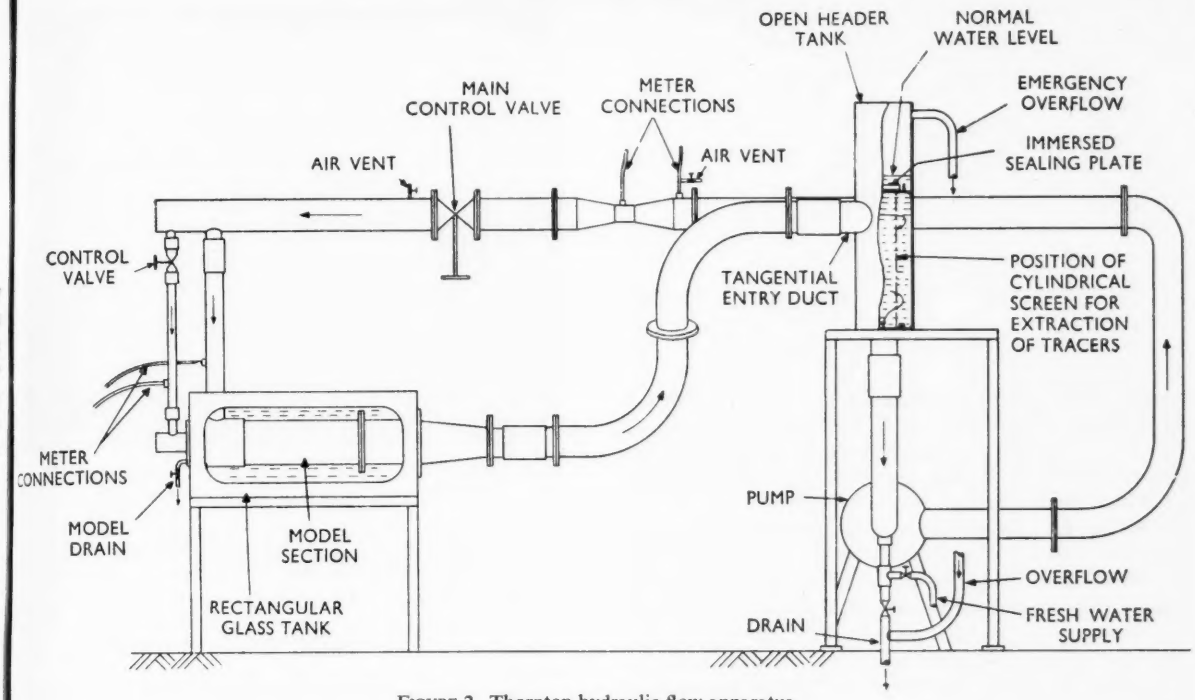


FIGURE 2. Thornton hydraulic flow apparatus.

(*ii*) The use of water instead of air provides similarity at a given linear scale at much lower velocities, which facilitates observation and recording of the flow details; the use of water also permits the matching of the density of the tracers to that of the fluid, and furthermore results in excellent optical clarity through the transparent models.

This has therefore been the principal method used at Thornton for the investigation of flow in continuous combustion systems.

2. The Experimental Technique

A detailed account of the apparatus and of some of the detail techniques has already been published[2], but a few of the salient features are reiterated briefly.

2.1. THE WATER CIRCULATING SYSTEM

A continuous-flow, closed-circuit system is used (Fig. 2), the water only being changed when dirty or when draining is necessary during modifications to the models.

The models on test are made largely in Perspex or similar material, by moulding and fabrication, and those items which have not to be transparent are made in brass. They are situated within a water-filled rectangular glass tank, which reduces optical distortion and prevents external condensation on the model. When three-dimensional combustion systems are under investigation, the models are usually scaled to about 8 in. overall diameter or major width. In addition, a rectangular-section tunnel is available for two-dimensional investigations.

The apparatus includes a semi-open elevated tank which, among other functions, facilitates the introduction of tracers and which is provided with a detachable screen for the removal of solid tracers from the circulating stream. It is frequently convenient to observe the complete flow field continuously, in which case solid tracers are allowed to circulate with the stream.

2.2. VISUALISATION AND RECORDING OF FLOW

The motion of the water is made apparent by the presence of a tracing material which follows the stream in adequate detail. For some purposes, where the fluid velocities are relatively high and the rates of acceleration are low, air bubbles may be used as tracers without excessive error. Air bubbles in water have rather poor reflectivity, but they are very conveniently introduced when local flow details are under observation and there is, therefore, sometimes a good case for using them. In most work, however, it is preferable to use solid tracers of similar specific gravity to the surrounding fluid. There are several possibilities; spherical particles of impure polystyrene have been used at Thornton, since they were obtainable with suitable properties. Particles of the desired size and density are selected by sieving and flotation. Tracers of 0·010 to 0·020 in. diameter are commonly used.

The illumination of either air or polystyrene tracers is provided by means of a 2kW. tungsten line-filament lamp or (for photography) a 1000 Joule xenon-filled flash tube, either lamp being mounted in a housing with adjustable apertures (Fig. 3) which permit the variation of beam width from a thin sheet to the full width of the

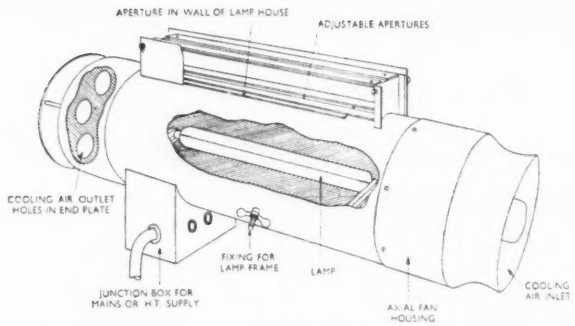

APERTURE IN WALL OF LAMP HOUSE
ADJUSTABLE APERTURES
COOLING AIR OUTLET HOLES IN END PLATE
FIXING FOR LAMP FRAME
LAMP
JUNCTION BOX FOR MAINS OR H.T. SUPPLY
AXIAL FAN HOUSING
COOLING AIR INLET

FIGURE 3. Arrangement of lamp house.

model. The normal arrangement of the apparatus for the photographic recording of flow data is shown in Fig. 4. The lighting equipment is similar to that used by Howes and Philip[3], and has been described in detail by Winter and Deterding[2].

Where the photography of a particular tracer or cloud of tracers is necessary over a relatively long period of time (*i.e.* several seconds), photography by tungsten light has been found unsatisfactory because of the increase of background response relative to the response of an individual tracer. For such cases, a technique has been developed in which polystyrene tracers with a luminescent coating are illuminated with ultra-violet light and photographed through a filter which, preferentially, transmits the luminescent radiation. This approach has been pursued because there are many detail problems in the behaviour of combustion systems which cannot be solved solely by Eulerian techniques (*i.e.* by the study of the history of fixed points in space, particularly of "steady" and "mean" phenomena) but which require also a Lagrangian type of treatment to establish the variations and extremes in the factors involved.

For ultra-violet illumination, the lighting units consist of six 125W. mercury vapour filter lamps, mounted in two groups of three, one group above and one below the model tank, as shown in Fig. 5. Photography is normally achieved by a single camera at position *A*, but alternative camera positions *B*, *B* may be used to

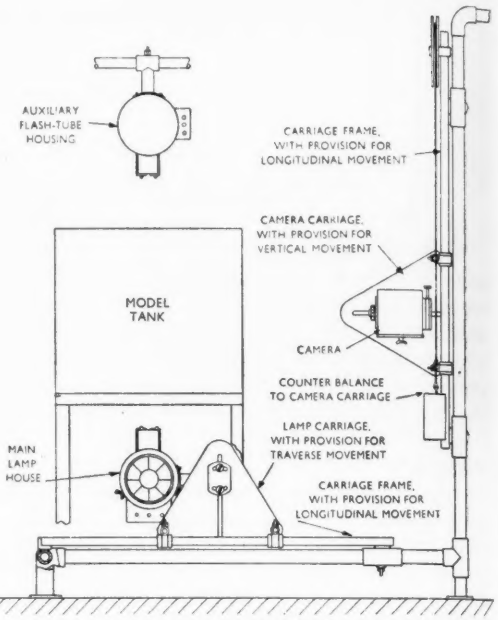

AUXILIARY FLASH-TUBE HOUSING
CARRIAGE FRAME, WITH PROVISION FOR LONGITUDINAL MOVEMENT
CAMERA CARRIAGE, WITH PROVISION FOR VERTICAL MOVEMENT
MODEL TANK
CAMERA
COUNTER BALANCE TO CAMERA CARRIAGE
LAMP CARRIAGE, WITH PROVISION FOR TRAVERSE MOVEMENT
MAIN LAMP HOUSE
CARRIAGE FRAME, WITH PROVISION FOR LONGITUDINAL MOVEMENT

FIGURE 4. Arrangement of optical equipment.

record simultaneously the projection of a flow trace on two mutually perpendicular planes if three-dimensional data are required.

Photography of a moving tracer by means of the flash tube produces, because of the flash characteristics, an image of varying intensity along its direction of motion, so that the recorded trace tapers from the beginning to the end of its path. Examples of such traces are shown in Fig. 6. Flash photographs of this type indicate the instantaneous components, in the plane observed, of both the direction and the velocity of the fluid at the position of each tracer, *i.e.* each trace represents a flow vector. In the turbulent flow systems usually studied by this method, a type of mean flow pattern in a centre section through a model can be derived by averaging at various positions the vectors recorded in a succession of photographs, as shown in Fig. 7. The section to be studied is made visible by means of a thin sheet of light, which is obtained by stopping down the apertures of the lamp housing to about a one-tenth inch gap.

When the ultra-violet system of lighting is used, a time base is automatically imposed by the use of a mercury discharge light source. The photographic record shows a variation in light intensity at the frequency of the mains voltage (Fig. 8).

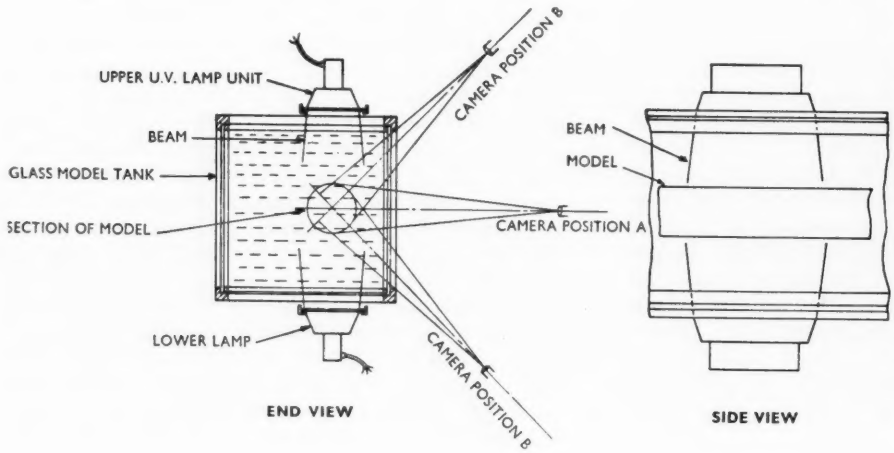


FIG. 5. Diagram of arrangement for ultra-violet photography.

FIGURE 6. Typical flash photograph of polystyrene tracers in a model of a combustion chamber.

These methods of photography, supplemented if required by the use of the tungsten lighting, either with or without calibrated shutters for exposure timing, permit the recording of flow details both qualitatively and semi-quantitatively. In addition, flow details may be observed visually by means of the continuous lighting, and this is frequently of considerable value.

3. Application of the Techniques

By the suitable selection and combination of lighting, tracer type, means of tracer injection and camera operation, many diverse phenomena can be studied. Some ways in which the visualisation techniques have been applied at Thornton follow.

3.1. SKIN COOLING

The liner walls of combustion chambers are frequently protected from excessive heat by the use of an annular arrangement of air jets over the inside surface. This method depends for its success on the maintenance of reasonably steady flow of the fluid in contact with the wall for as great a distance as possible before appreciable mixing occurs between the jet and

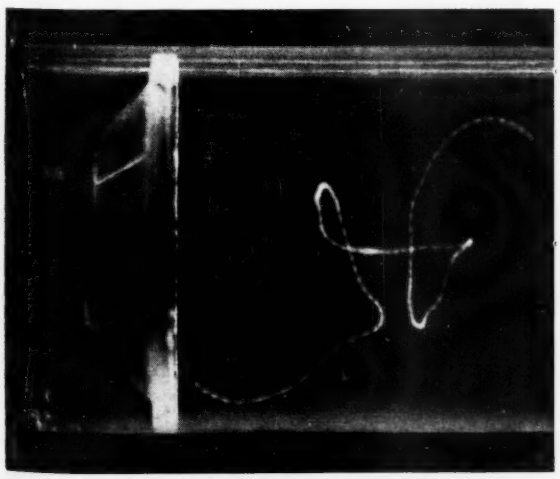


FIGURE 8. Tracer paths photographed by ultra-violet light.

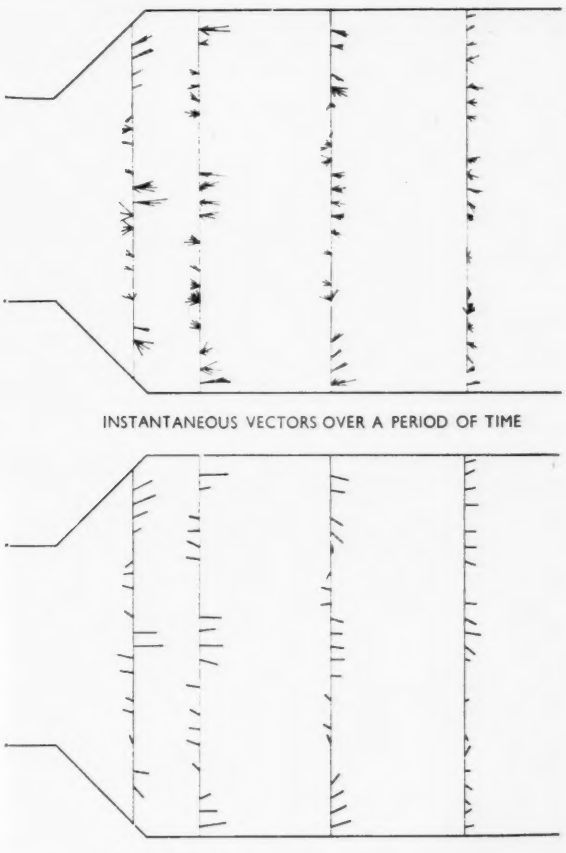


FIGURE 7. Vectors of flow components in a plane at the centre of a cylindrical flame tube.

the fluid in the flame zone. In order that the proportion of fluid used in the cooling jets shall not be unreasonably high, and that the mass rate of mixing of this cold stream with the flame gases shall not be excessive, and therefore possibly detrimental to combustion, it is usual to confine the jets to a thin layer and to replenish this layer at suitable intervals along the length of the flame zone. The kind of arrangement normally used is illustrated in Fig. 9.

In such a system, the persistence of each ring of jets along the wall determines the maximum allowable distance between successive rings of jets for adequate blanketing of the wall. This is a problem which, under simple flow conditions, could readily be solved by calculation, but the mixing conditions between the annular jets and the highly turbulent three-dimensional flow in the flame-stabilising region are frequently difficult to define. The behaviour of the jets under complex conditions can be studied by means of the water visualisation method, and although the mixing conditions in the presence of combustion will differ somewhat from the constant density conditions, the differences in jet persistence tend to be fairly small in most cases and some allowance can be made for them.

Since the important part of the stream under observation is not subject to high centrifugal effects and

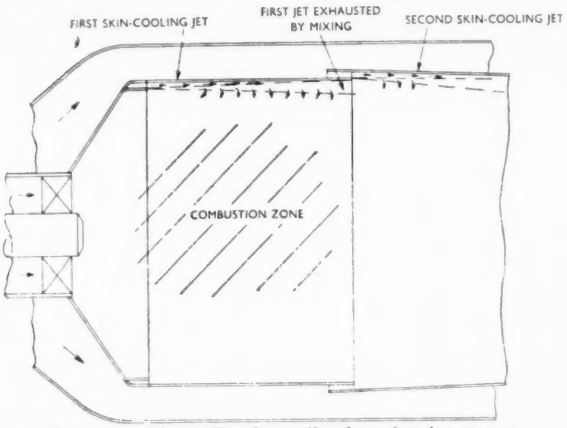
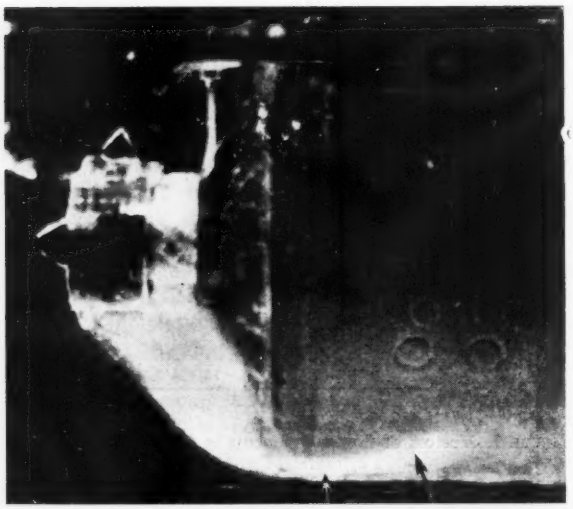
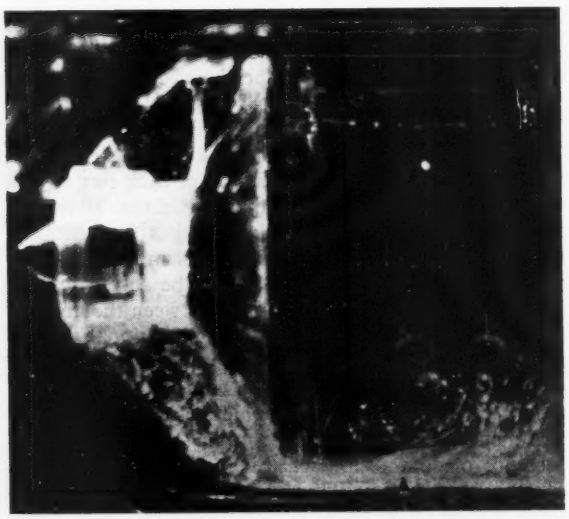


FIGURE 9. Skin cooling for walls of combustion system.



Skin-cooling port. Skin-cooling jet.
Photograph by continuous light.



Skin-cooling jet.
Photograph by electronic flash.

FIGURE 10. The visualisation of a local flow detail by means of air-bubble tracers.

moves at a relatively high velocity, there is generally no need for the density of the tracers to be matched to that of the fluid, provided that the tracers are very small. Air bubbles can therefore be used in this case, and this is particularly convenient in that bubbles pass unhindered through the small apertures associated with skin-cooling passages and they are easily introduced as a local stream where required. The technique used for this purpose, therefore, involves the injection of a stream of fine bubbles, by means of a probe, immediately upstream of the entry to the skin-cooling passage at the uppermost part of that section of the model. A fairly narrow beam of light is projected vertically upwards through the longitudinal axis of the model and the tracers are observed and recorded through the side wall. Photography is best achieved by the use of the electronic flash, but the tungsten lighting has also been found useful for obtaining photographs at rather longer exposures (the maximum duration of the flash in the Thornton apparatus is about 6 milliseconds).

Figure 10 shows typical records of skin-cooling flow obtained by this method. The persistence of the jet along the wall and the inward mixing which destroys

Skin-cooling jet

Skin-cooling jet.

FIGURE 11. Skin-cooling jet demonstrated by means of tracers in main stream only.

the identity of the jet can be seen clearly in these photographs.

It is also instructive to observe the degree of penetration of the main flow into the skin-cooling stream by the introduction of tracers into the main air director. In this case, also, air bubbles may be used provided that they are not assumed to show the true flow pattern of the main stream in the more complex regions remote from the wall. Fig. 11 is an example.

3.2. MIXING OF DILUTION STREAM

A common problem in gas turbine combustion systems concerns the introduction of the dilution air so that the requisite degree of mixing occurs between this air and the combustion gases within the limited space usually available. Because of the difference in density of the two streams under normal operating conditions, observations of the constant density case cannot give a true picture of the normal mixing pattern. This is a case, however, where the water method can be applied comparatively. For example, the effects of modified dilution-air injection arrangements on jet penetration and mixing can be studied qualitatively and even, in terms of orders of difference, quantitatively. It is also often possible in the light of experience to make a reasonable allowance for the effects of density changes.

Polystyrene tracers have been used for the study of this problem, but otherwise the recommended technique is similar to that used for skin-cooling observations. Tracers are admitted to the dilution stream at a position immediately upstream of one of the dilution ports and their paths through the model are recorded photographically. Satisfactory records may thus be obtained by the use either of plain polystyrene pellets illuminated by the tungsten light, or of luminescent tracers illuminated by the ultra-violet source. A composite picture of the motion of a large number of tracers entering through a single dilution port can thus be obtained, showing the penetration and distribution of this one jet. A tracing of a typical record of this kind is shown in Fig. 12.

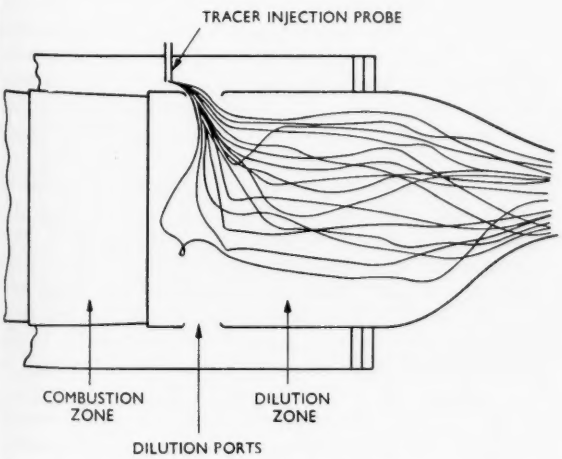


FIGURE 12. Dilution jet penetration illustrated by tracer paths.

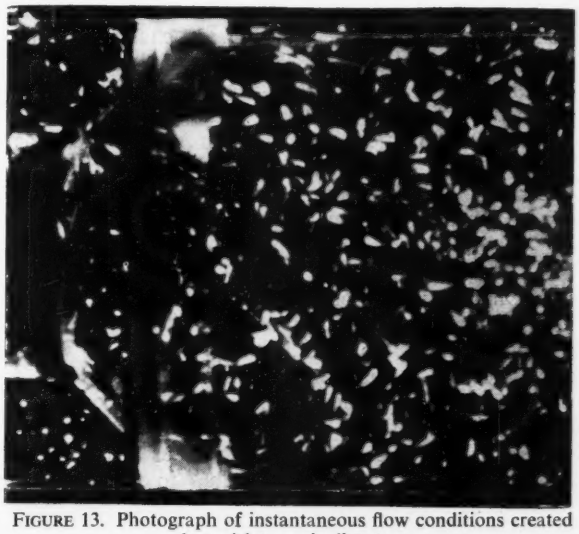


FIGURE 13. Photograph of instantaneous flow conditions created by swirl-type air director.

3.3. EXPLORATION OF COMPLETE FLOW FIELDS

In the conventional types of gas turbine combustion chamber, regardless of whether the flow pattern is mainly two-dimensional or whether it is of the kind which depends on a strong rotational motion about the longitudinal axis, it is of particular interest to study the components of flow in a plane through the longitudinal axis, since the two-dimensional part of the flow pattern is closely related to the flame-holding characteristics of the system. An axial section may be viewed as already noted, by the use of a narrow, flat beam of light, which for purposes of photography is provided by the flash apparatus. Polystyrene tracers are circulated continuously in the water at a concentration of about 0·1 per cent or less, depending on their size.

Successions of flash photographs of this type, of which Fig. 13 is a typical example, are used for the derivation of mean vector diagrams such as that shown in Fig. 14. From the vector diagrams, the order of the proportional flow through each section of the model may be determined, and Fig. 15 (taken from Reference 1) shows an example of the derived information for recirculating flow in the flame zone of a combustion system with two arrangements of air director.

It has been found that in practical cases the complete flow pattern obtained with water is to a considerable degree representative of that which occurs under combustion conditions, the principal difference being

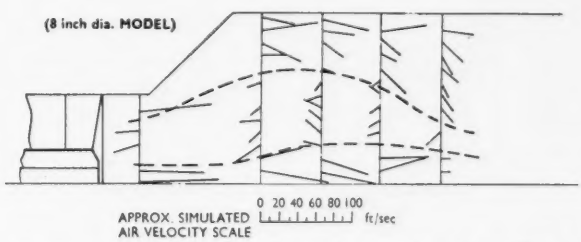


FIGURE 14. Result obtained by photography of water in a model of a combustion chamber. Comparable with Fig. 1.

in the length of the vectors in the downstream regions. As already demonstrated in Fig. 1, changes in the "cold" flow pattern and in the "cold" mass flow distribution due to changes in the air director may be reflected fairly closely at "hot" conditions, and during the study of particular combustion systems use has been made of the broad quantitative results of the water visualisation work in the analysis of the effects of equipment alterations on combustion performance.

3.4. RESIDENCE TIME

Owing to the turbulent and complex flow which normally exists in a gas turbine combustion system, the residence time of the gases in the primary zone, which may affect to a considerable extent the efficiency of a system operating either under high altitude conditions or on heavy liquid fuels with slow droplet burning rates, varies over a wide range. For various types of air director it is of considerable value to obtain comparative data on the range of gas residence time, and particularly on the minimum time.

This is one of several problems which have been studied by the use of individual luminescent tracers.

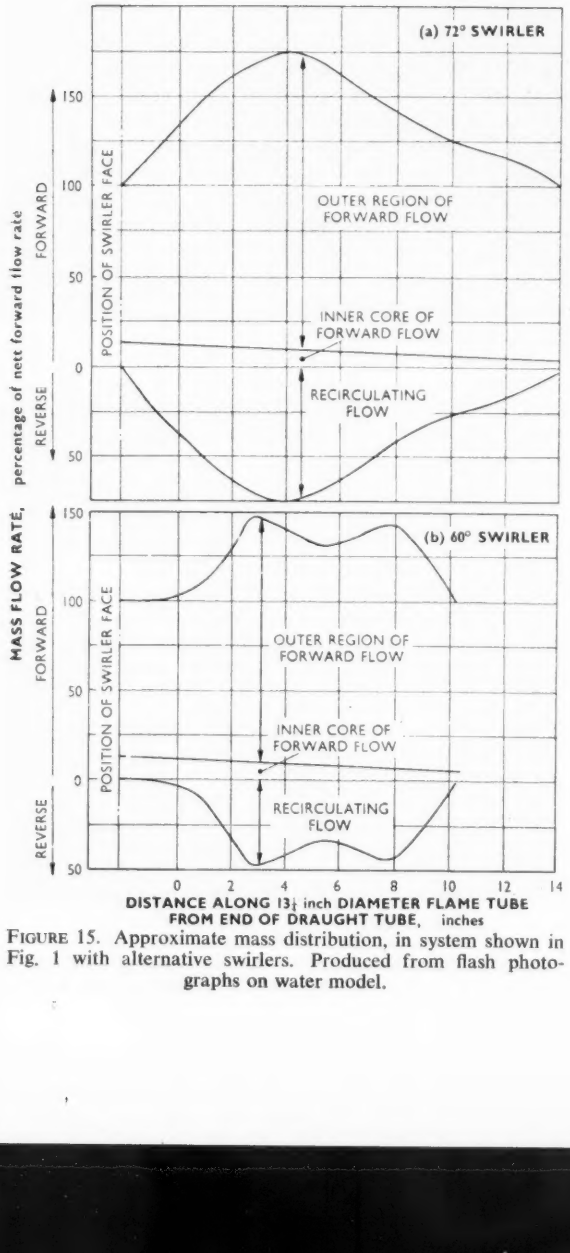


FIGURE 15. Approximate mass distribution, in system shown in Fig. 1 with alternative swirlers. Produced from flash photographs on water model.

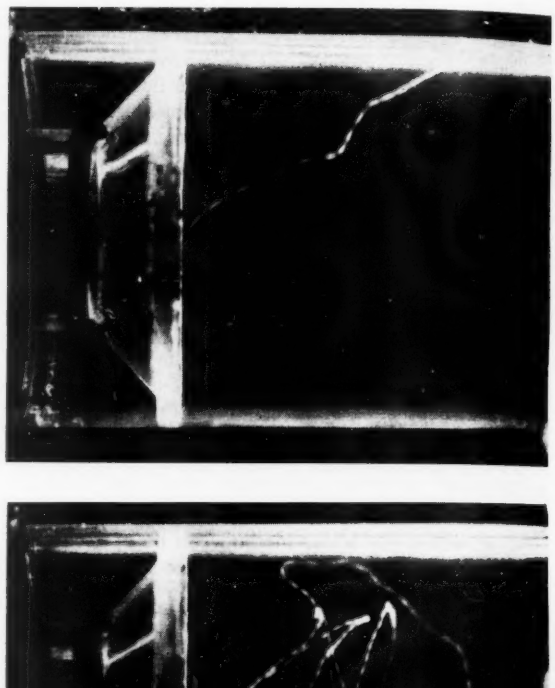


FIGURE 16. Examples of short and long residence times.

The technique involves the photography of a large number of such tracers introduced at random upstream of the air director. The residence time of each tracer within the part of the chamber defined as the burning zone (*i.e.* upstream of appreciable influence by the dilution zone) is then measured from the time-based record. Fig. 16 shows examples of the extreme records obtained in a particular case (*i.e.* very short and very long residence times). The mean flow pattern for this case is shown in two-dimensional form (*i.e.* without details of the axial swirl components) in Fig. 17. A graph showing the spectrum of residence times relative to the mean "straight-through" flow time, Fig. 18, indicates that in this system, operating without heat release, the minimum residence time of any fluid element was only about 33 per cent of the mean and 64 per cent of the fluid had a residence period less than the mean. This was balanced by the remainder of the fluid spending up to 350 per cent of the mean time in the burning zone.

The technique is restricted by the inability of tracers of the size used to simulate molecular motion, but useful information of a comparative nature can be obtained.

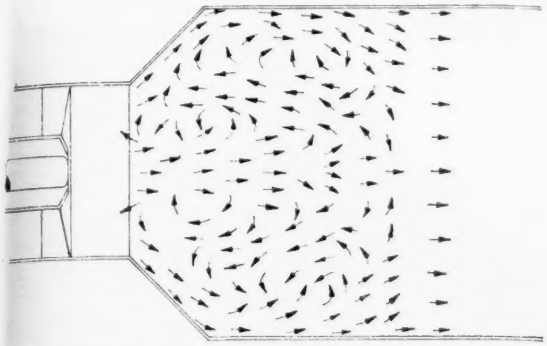


FIGURE 17. Mean directional flow pattern for system investigated.

3.5. THE DEVELOPMENT OF NEW DESIGNS

All the types of investigation so far described may be found useful in the particular problem of developing existing combustion equipment to give the requisite aerodynamic features for flame stabilisation and other associated functions. It is believed, also, that in suitable instances the study of water flowing in a model before the commencement of actual combustion testing is a convenient and economic method of ensuring that the basic hardware used for development will achieve a suitable flow system. Modifications to a Perspex model are easily and cheaply made and the results of the modification are readily appreciated. Both visual observation and photography are useful in this type of work.

An example of this kind of application of the water visualisation method is the development of a novel type of flame stabilising system of the type shown in Fig. 19. The idea behind this system was to provide an air director which would create a recirculating flow without the pressure losses associated with swirlers and discrete jets, and without the recirculation of flame products on to parts of the equipment which occurs with baffles and most other commonly used air directors. The flow pattern is created by the adhesion of an annular stream of air to the inside surface of a steeply diverging bellmouth by the sudden interruption of the boundary layer at the inside of the annulus; the face of the fuel injector is swept with clean air by a similar device.

A two-dimensional study was first carried out in this case, to prove the principle and indicate whether any particular problems might be encountered. This involved the visual study of a model in a rectangular tunnel, using polystyrene tracers in general circulation.

From this simple model sufficient information could be obtained for the basic design of a three-dimensional model as a preliminary to subsequent combustion work. Photographs of such a model, taken with general tracer circulation, are shown in Fig. 20. The upper photograph represents a case where the outer annular jet did not conform to the required flow path; the lower photograph shows the result of a modification which produced the intended type of flow.

It is obviously imperative that in a case like this the ultimate development is under combustion conditions, but in the particular instance quoted there would be

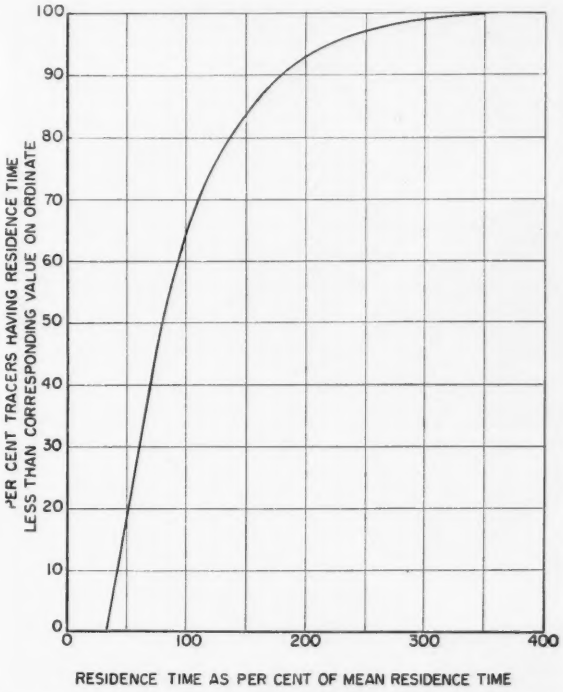


FIGURE 18. Spectrum of residence times of traces injected at random into the burning zone of a combustion system.

no point in proceeding to combustion tests if the possibility of obtaining suitable flow patterns were not established during the model tests. An examination of the "cold" flow conditions is of particular value in the development of an air-director system, such as that described, since the primary requirement is the creation of a suitably directed flow system, and this is not appreciably influenced in the initial stages by the changes in the density which occur in the flame zone.

3.6. PARASITIC LOSSES

During the visual study of complete combustion systems, much useful information can be obtained concerning the flow in the inlet and air-casing passages, and in particular, examples of inefficient passage design leading to avoidable pressure losses can be readily seen.

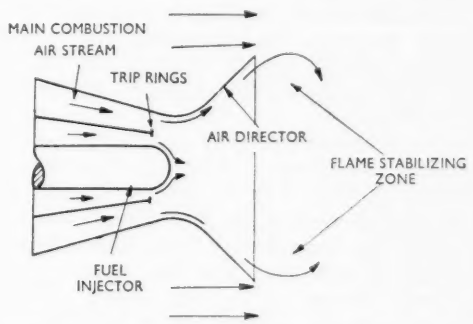


FIGURE 19. Thornton X.33 flame holder.

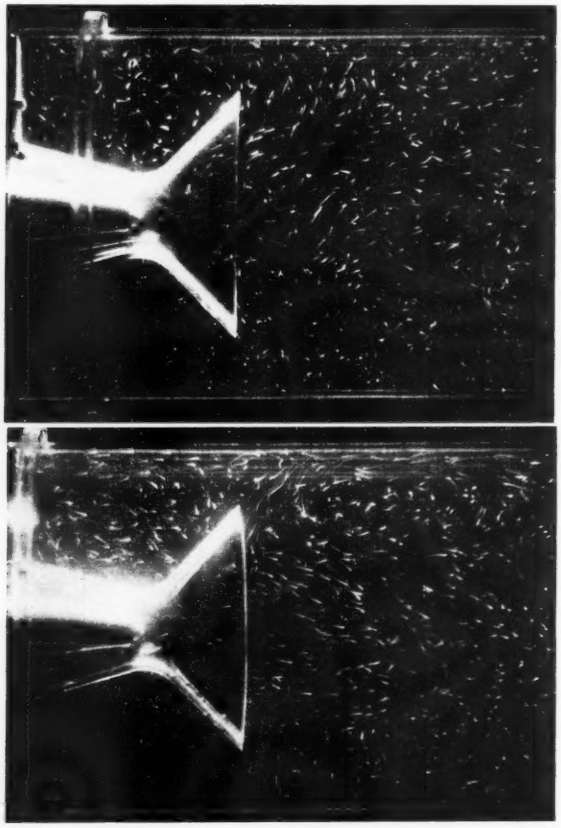


FIGURE 20. Experimental air director. Upper photograph shows undesirable flow, lower photograph shows intended flow pattern.

Fig. 21 shows an instance where bad design has caused losses by eddy formation in an air casing.

4. Limitations of the Techniques

It is important to recognise, in any particular case, the limitations of the water visualisation techniques as means for investigating combustion conditions.

In general, the water method gives a true picture of the air flow, in the absence of combustion, in equipment where compressibility effects may be ignored; that is, in most gas turbine combustion systems and in industrial furnaces and boilers. It does not indicate molecular mixing conditions, because of the size of tracer necessary for satisfactory observation; but the motion of the tracers, when of the correct density, is related to the overall mixing in the manner of a damped motion.

Density changes accompanying combustion modify the flow pattern in a system so that parts of the stream are accelerated, mixing rates of adjacent streams are changed and the division of the flow between various parts of the system is modified. Some types of flame zone, if examined separately from the dilution zone, are significantly affected by the heat release only in respect of local velocity changes, and it is possible in such cases to extend the "cold" data semi-quantitatively to the "hot" condition. It is only possible to do this

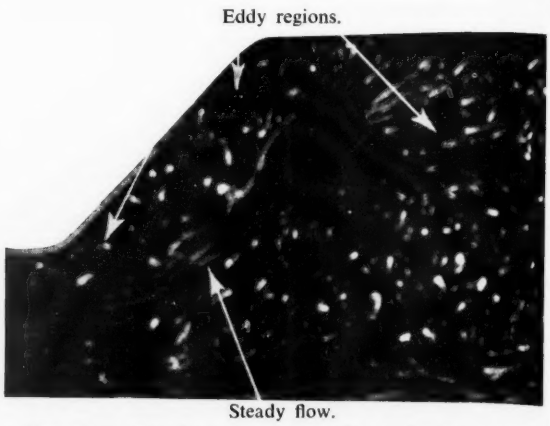


FIGURE 21. Flow in entry passages of a combustion system.

with complete confidence, however, if the type of system under examination has previously been studied under burning conditions, by probing or other techniques, so that the essential features of the flow modifications due to combustion are appreciated.

Certain flow phenomena, such as the penetration of dilution jets, are modified under combustion conditions by changes in velocity and momentum which can be roughly predicted. In other cases, *e.g.* the example given of the application of the techniques to air director development, combustion does not modify at all certain essential features of the flow. It is necessary, however, to remember that the water flow pattern may not be a true representation of the flow when flame exists, although qualitatively it will nearly always be closely similar.

Finally, it must be noted that, with due regard for the limitations, the water visualisation method possesses the distinctive feature of permitting direct observation of the flow. To see a phenomenon is often an important step towards appreciating and understanding it, and in the field of combustion the behaviour of the hot gases within a metal casing is frequently something of a mystery. The ease with which the flow may be studied visually is a major justification of the water method.

ACKNOWLEDGMENTS

The author wishes to acknowledge his indebtedness to the experience of other workers on the subject of flow visualisation during the initial stages of developing his own techniques, particularly to Dr. J. H. Chesters of the United Steel Companies and to Dr. E. C. Robeson of the Ministry of Supply. Acknowledgment is also made to the Directors of "Shell" Research Limited for permission to publish this paper.

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Ninety-Third Annual Report of the Council 1957 - 1958

FOR the third successive year Members of the Society have been favoured with an Address by the President, for Sir George Edwards has followed the practice re-started by his immediate predecessors, Mr. E. T. Jones and Mr. N. E. Rowe.

Once more the Address was followed by a Reception; on this occasion it was held at 4 Hamilton Place, and this appears to have been a popular venue with the Members, who are pleased to talk with each other in the pleasant and familiar surroundings at Hamilton Place.

During a visit to the U.S.A. at the beginning of 1958 the President was able to attend the Honours Dinner of the Institute of the Aeronautical Sciences, when he was given the opportunity of presenting the Society's Gold Medal to Dr. J. C. Hunsaker, who was unable to come to London to receive it.

The Sixth Anglo-American Aeronautical Conference was held in September 1957 at Folkestone and was much enjoyed by American and British alike, not least by the ladies.

Again the Course on Air Transport has been successful, and the Third Course is to be held at Oriel College, Oxford, during March/April of this year. The number of Students remains high, and there are no indications that the demand for this Course has been satisfied.

Membership has increased, and has now reached the 10,000 mark. This gives the Council every satisfaction, but the effort to maintain these satisfactory increases shown over the past two years must be continued. The increase in the number of Students is to be noted.

The Inauguration of the Guided Flight Section, under the Chairmanship of Dr. G. W. H. Gardner, has proved to be a most popular step, for lectures initially planned to be held in the Library have been transferred to larger lecture halls, for the numbers attending could not be accommodated in the Library.

Arrangements for the First International Conference of the Aeronautical Sciences to be held in Madrid are proceeding and preliminary details are published in this Journal. It is hoped that there will be a good delegation from the United Kingdom.

A Joint Committee has been established for the administration of Higher National Certificates and Diplomas in Aeronautical Engineering. This Committee comprises representatives of the Ministry of Education, The Institution of Mechanical Engineers and the Society.

The Council for the year 1957-1958 is as follows:-

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Election of Officers of the Society

PRESIDENT

SIR GEORGE EDWARDS, C.B.E., B.Sc.(Eng.), F.R.Ae.S., President of the Society for the year 1957/1958 took office at the Annual General Meeting of the Society held on 8th May 1957.

PRESIDENT-ELECT

SIR ARNOLD A. HALL, M.A., F.R.S., F.R.Ae.S., Vice-President of the Society and Technical Director of the Hawker Siddeley Group, was elected the President-Elect of the Royal Aeronautical Society for 1958/1959. He will take office as President in May 1958.

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The following were elected Vice-Presidents of the Society at their Meeting on the 23rd May 1957:—

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Code Drafting Committee on the Proposed Code of Practice on the Measurement and Abatement of Radio Interference in Aircraft	Mr. J. M. Furnival
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British Conference on Automation and Computation	Professor E. J. Richards
British National Committee for Non-Destructive Testing	Mr. B. S. Shenstone until March 1958 Mr. I. Grant-Murray from March 1958

Annual General Meeting

The 92nd Annual General Meeting of the Society was held on Wednesday 8th May 1957, in the Offices of the Society, with Mr. E. T. Jones, President, in the Chair. The Report of the Council for the year and the Accounts for 1956-57 were before the assembled Members and were adopted unanimously.

The President reported the following elections to fill the vacancies on the Council:—

*Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S.
J. R. Cownie, B.Sc.(Eng.), Grad.R.Ae.S.
*Sir William S. Farren, C.B., M.B.E., F.R.S., M.I.Mech.E., Hon.F.I.A.S., F.R.Ae.S.
*G. W. H. Gardner, C.B., C.B.E., D.Sc., B.Sc., F.R.Ae.S.
*P. G. Masefield, M.A.(Eng.), Hon.F.I.A.S., F.R.Ae.S.
*E. S. Moult, Ph.D., B.Sc.(Eng.), M.I.Mech.E., F.R.Ae.S.
S. Scott Hall, C.B., M.Sc., D.I.C., F.C.G.I., F.I.A.S., F.R.Ae.S.

* *Re-elected to Council.*

The Secretary read the names of those elected to Fellowship:—

George Oswald Anderson
Ronald John Atkinson
Edward Hugh Bateman
Ralph Beasley
Geoffrey Mungo Buxton
Dr. Walter Cawood
Geoffrey Dean Dawson
Reginald William Dunn
Leonard Sidney Greenland
Gustaf Gudmundson
Geoffrey William Hall
Ian Malcolm Hamer
Edward Henry Heinemann
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Dr. Douglas William Holder
Professor Owen Alfred Saunders
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Rear Admiral Selden Booth Spangler
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Samuel Paul Johnston
James Arthur Kay
Jerome Fox Lederer
John C. Leslie
Sidney Walter Douglas Lockwood
Professor Alfred John Murphy
Professor Alfred Salem Niles
James Norman
Paul Robert Owen
Ronald Charles Pankhurst
James Denning Pearson
Courtland Davis Perkins
Charles Willis Prower
Frederick Gerald Carlton Sandiford
John Stack
William Arthur Summers
Robert William Symmons

The President presented the following Prizes:—

George Taylor (of Australia) Gold Medal	Mr. G. Forrest and Mr. K. Gunn
Simms Gold Medal	Mr. E. G. Broadbent
Orville Wright Prize	Dr. B. S. Stratford
Edward Busk Memorial Prize	Mr. I. M. Davidson
Herbert Akroyd Stuart Memorial Prize	Dr. J. S. Clarke
Branch Prize	Mr. E. R. Major
Royal Aeronautical Society Navigation Prize	Mr. R. A. Burberry
Usborne Memorial Prize	Mr. T. M. Corson

Mr. Jones then inducted his successor, Sir George Edwards, to the Chair and, as he did so, wished him every success and happiness in the Office.

Memorial and Special Lectures

Wilbur Wright Lecture

The 45th Wilbur Wright Memorial Lecture was held in London on the 13th September 1957, and the subject was "Advanced Education and Academic Research in Aeronautics" by Dr. Clark B. Millikan, Hon.F.I.A.S., F.R.Ae.S. As is customary, the major honours and awards of the Society were also presented. (The full Report was published in the December 1957 Journal.)

Louis Bleriot Lecture

The Eleventh Louis Bleriot Lecture was held in Paris on the 5th March 1958 and the subject was "The Future of Aeronautical Research" by Professor W. J. Duncan, C.B.E., D.Sc., F.R.S., F.R.Ae.S. (The full Report will be published in the May 1958 Journal.)

British Commonwealth Lecture

The Thirteenth British Commonwealth Lecture, "Why Airlines are Hard to Please" by Mr. B. S. Shenstone, was held in London on the 27th March 1958.

The First Lanchester Memorial Lecture

The Society was greatly honoured by Dr. Theodore von Kármán's acceptance of the Council's invitation to read the First Lanchester Memorial Lecture on 9th May 1957 in London. (The full Report was published in the February 1958 Journal.)

Guided Flight Section

Many Members will have seen the announcement of the formation of a Guided Flight Section of the Society.

The Section is under the general direction of the Council, within the Charter and By-Laws of the Society, but has a large measure of autonomy in the conduct of its affairs. To inaugurate the Section a Steering Committee was formed; this has now become the Section's first Committee. This Committee is as follows:—

Dr. G. W. H. Gardner, C.B., C.B.E., B.Sc., F.R.Ae.S. (*Chairman*), Director, Royal Aircraft Establishment.
Mr. H. H. Gardner, B.Sc., F.R.Ae.S., Director and Chief Engineer, Military Aircraft, Vickers-Armstrongs (Aircraft) Ltd.
Mr. M. J. Brennan, B.Sc., F.R.Ae.S., Chief Designer, Saunders-Roe Ltd.
Dr. R. R. Jamison, B.Sc., A.F.R.Ae.S., Engineer-in-Charge Ram-Jet Development, Bristol Aero-Engines Ltd.
Mr. H. C. Pritchard, B.A., F.R.Ae.S., formerly Deputy-General Manager, Elliott Bros. (London) Ltd. (now Cambridge Instrument Co. Ltd.)
Mr. G. G. Roberts, M.Sc., A.F.R.Ae.S., Technical Director, Smiths Aircraft Instruments Ltd.

The Committee will normally be elected by the members of the Section in a postal ballot. This election will be held in the Spring of 1958. Proposals for Membership of the Committee will be announced later.

A lecture programme has been arranged and the first lecture was given on 21st November 1957 by Mr. J. E. Serby, C.B.E., B.A., F.R.Ae.S., Director-General of Guided Weapons, Ministry of Supply, on "Guided Weapons and Aircraft—Some Differences in Design and Development." This lecture was held at the Royal Institution, Albemarle Street, and was presided over by the President, Sir George Edwards. (The lecture was published in the March 1958 Journal.)

Lectures

The following Main, Section and Guided Flight Section Lectures have been read before the Society in 1957/58:—

1957

Tuesday 8th October: Section Lecture—Some Thoughts on Non-Linear Problems in Aerodynamics. P. J. Dunton, A.F.R.Ae.S. (*To be published.*)

Tuesday 22nd October: Section Lecture—Aircraft Instrumentation for Flight Test Purposes. R. R. Duddy, A.F.R.Ae.S., and I. McLaren, A.R.Ae.S.

Tuesday 12th November: Section Lecture—Some Problems of Stability and Control. H. H. B. M. Thomas, A.F.R.Ae.S.

Tuesday 19th November: Section Lecture—The Supersonic Wind Tunnel. Dr. W. F. Hilton, F.R.Ae.S. (*To be published.*)

Thursday 21st November: GUIDED FLIGHT SECTION—Guided Weapons and Aircraft—Some Differences in Design and Development, J. E. Serby, F.R.Ae.S.

Tuesday 26th November: SECTION LECTURE—Some Aspects of Refrigeration in Supersonic Aircraft, E. J. Gabbay, A.F.R.Ae.S. (*To be published.*)

Tuesday 3rd December: SECTION LECTURE—Some Techniques of Engine Testing under Simulated Icing Conditions, O. R. Ballard, A.F.R.Ae.S., and P. J. Sharp.

Thursday 12th December: MAIN LECTURE—Ram-Jets, R. P. Probert.

Tuesday 17th December: SECTION LECTURE—Comparison of Ducted Fan, By-pass and Straight Jet Engines, Dr. S. G. Hooker, F.R.Ae.S.

1958

Thursday 2nd January: YOUNG PEOPLE'S LECTURE—Some Aspects of Test Flying, A. W. Bedford, A.R.Ae.S.

Wednesday 15th January: MAIN LECTURE AT LEICESTER BRANCH—Aircraft Engines, A. A. Lombard, F.R.Ae.S.

Tuesday 21st January: SECTION LECTURE—Environments and Environmental Testing, P. J. Duncton, A.F.R.Ae.S., and T. F. R. George, A.F.R.Ae.S.

Thursday 23rd January: GUIDED FLIGHT SECTION—Guidance and Control, L. H. Bedford. (*To be published.*)

Thursday 13th February: MAIN LECTURE—The Application of the Theory of Stability in Structural Design, H. L. Cox, F.R.Ae.S.

Tuesday 18th February: SECTION LECTURE—Aeroelastic Problems Associated with High Speeds and High Temperature, E. G. Broadbent, A.F.R.Ae.S. (*To be published.*)

Thursday 20th February: THE FIRST TRENCHARD MEMORIAL LECTURE AT HALTON BRANCH—Marshal of the R.A.F., Sir Dermot Boyle.

Tuesday 25th February: GUIDED FLIGHT SECTION—Guided Flight Trials, R. W. M. Boswell. (*To be published.*)

Wednesday 26th February: PRESIDENTIAL ADDRESS—Sir George Edwards, F.R.Ae.S.

Wednesday 5th March: THE ELEVENTH LOUIS BLERIOT LECTURE—IN PARIS—The Future of Aeronautical Research, Professor W. J. Duncan, F.R.Ae.S.

Thursday 13th March: MAIN LECTURE AT CHRISTCHURCH BRANCH—Flight Tests of a Meteor Aeroplane fitted with Jet Deflection, P. F. Ashwood, A.F.R.Ae.S., and D. Lean, A.F.R.Ae.S.

Thursday 20th March: GUIDED FLIGHT SECTION—Problems in the Development of a Guided Weapon, J. Clemow. (*To be published.*)

Thursday 27th March: THE THIRTEENTH BRITISH COMMONWEALTH LECTURE—Why Airlines are Hard to Please, B. S. Shenstone, F.R.Ae.S.

The following Lectures will complete the Programme:

Thursday 10th April: MAIN LECTURE—Guided Weapons and Aeronautics, Dr. R. Cockburn.

Tuesday 15th April: SECTION LECTURE—The Problems of Vertical Take-off, Dr. C. T. Hewson.

Thursday 15th May: 46TH WILBUR WRIGHT MEMORIAL LECTURE—Automatic Flight—The British Story, Dr. G. W. H. Gardner, F.R.Ae.S.

Joint High Altitude and Satellite Rockets Symposium

A Symposium, organised jointly by the College of Aeronautics, the Royal Aeronautical Society and the British Interplanetary Society, was held on 18th to 20th July 1957 at the College of Aeronautics. The proceedings are being published by the Society and will be available about the middle of this year.

The Sixth Anglo-American Aeronautical Conference

The Sixth Anglo-American Aeronautical Conference, organised by the Society, was held from 9th to 12th September 1957 in Folkestone. Visits were arranged from the 2nd September for the American visitors to research establishments and firms in the aircraft industry and also to the S.B.A.C. at Farnborough. The proceedings of the Conference are being published by the Society and will be available about the middle of the year.

Air Transport Course, Oriel College, Oxford

The Second Air Transport Course, organised by the Society, was held from 25th March to 13th April 1957, when 35 Students attended. The Third Air Transport Course is being held from 23rd March to 11th April 1958.

Divisions

The Overseas Divisions of the Society continue to prosper and maintain their high standard of activity. Not only is there frequent postal communication between them and the Society, but there have been many personal contacts made by visitors to this country. Few members miss the opportunity of calling at 4 Hamilton Place to give first hand news of their Division.

Among the many visitors were Air Commodore G. N. Roberts and Air Commodore G. Carter, the President and immediate Past-President of the New Zealand Division. They were able to attend the Garden Party at Wisley, and there they met many old acquaintances. Mr. W. H. Dunn, also of the New Zealand Division, was another welcome caller.

From the Southern African Division came Mr. P. S. Deary, the Honorary Treasurer, and Mr. G. D. Matchett, who attended the Anglo-American Conference at Folkestone.

The Divisions wish to make contact with any visitors to their Country and it is recommended that the Secretary be informed of intended visits and he will write to the Divisional Secretary so that it might be possible to arrange a lecture or talk by the traveller.

The Council wish to thank all the Members of the Councils of the Divisions and the Committees of the Branches for their enthusiastic support of the Society's work.

Branches

The number of Branches of the Society still stands at twenty-eight. The Lecture Programmes at these Branches reflect their enthusiasm and interest in the aims and purposes of the Society.

The custom of holding Main Lectures at Branches has been continued and in 1958 a Main Lecture was held at the Leicester Branch and one at the Christchurch Branch.

The First Trenchard Memorial Lecture was held at the Halton Branch. The arrangements made by the Branch Committee, especially by the Chairman and by the Secretary, were excellent. It was fitting that the Lecture was given by Sir Dermot Boyle, and that Lady Trenchard and the present Lord and Lady Trenchard were present to listen to the tribute paid to the memory of the late Lord Trenchard.

The President, during his term of office, has been most impressed by the spirit he has found in the Branches and mentioned at his Presidential Address that the number of Branch members in the United Kingdom had now reached a total of about 6,000; these were not members of the Society.

The Weybridge Branch has a membership of 824 and is still the Branch with the largest membership. An up to date list of the Branches giving the names of their Officers

is published in every alternate issue of the Journal. (A complete list of Branches is published in this April 1958 Journal.)

During the past year there have been changes in the Office Bearers of some of the Branches; Secretaries, due to pressure of work, have resigned but there has always been a replacement ready to take over. To retiring Secretaries, the Council of the Society extend their thanks, and incoming Secretaries the Council would welcome and wish success to their efforts.

Membership

In the two years since the launching of the Membership drive in January 1956 the Society's overall membership has increased by 1,400 and at 31st December 1957 stood tantalisingly close to ten thousand at 9,953. The steep upward slope of the curve which began in 1956 has flattened very little and the rate of intake of new members is still about equal to the peak rate during the War.

The number of newly elected members amounted to 924 this year, compared with 979 in 1956. Losses due to resignations and terminations were rather higher—237, compared with 203 last year.

Once again the majority of the new members has been in the class of Associate Fellowship, *i.e.* 46 per cent, a similar percentage to the 1956 figure. Graduates diminished in number by 30 (197 transferred to Associate Fellowship), but Students, with a net increase of 209, were very little down on 1956.

The table below shows the membership figures as at 31st December 1957. A graph showing the membership growth from 1939 to 1957 is published with the Presidential Address on p. 240 of this Journal.

Graduates' and Students' Section

During the year the Graduates' and Students' Committee organised a wide range of lectures, film shows, visits and social events. In addition the Committee considered a series of matters affecting the interests of Graduates and Students.

Lectures and Visits

Seven lectures and two film shows have been held; an additional lecture had to be cancelled at the eleventh hour owing to security restrictions and a film show was arranged in its place.

Average attendance at lectures and film shows was 55. The most popular lecture was "Flight Testing Procedures at Supersonic Speeds" by Wing Cdr. R. P. Beamont; extensive reports of this appeared in the Aeronautical and National Press and on the radio.

As a general rule lectures were sought from well-known authorities. Experience has shown that lectures by experts who give a relatively broad survey of a subject are more popular than those lectures which concentrate on very narrow and specialised aspects of aeronautics.

Eight visits were arranged during the year to aircraft, aero-engine and motor companies, to atomic, rocket and road-traffic research establishments and to a brewery. Most of the visits were very well attended, in particular those to aircraft companies and to Harwell. In several cases where numbers were limited the visits were heavily over-subscribed.

Party and Dance

The Committee organised an informal summer party on 21st June and the usual annual dance on 29th November. Both were well attended.

The Committee's policy with both the party and the dance is to provide a full evening's entertainment at a price which even the most impecunious student can afford. The price of a ticket includes refreshments; there are no extras to pay after the ticket has been bought. This policy is obviously popular with members.

The Committee budgets for social events on the basis that a small loss will be made. The Section's annual grant enables this to be done and thus helps social events to be arranged at a reasonable cost to members.

Other Activities

The Section's page in the Journal is used for the discussion of matters which affect Graduates and Students and for reports on lectures and visits.

During the year a correspondence on National Service has been published. The Committee asked the Ministry of Labour for an official statement of policy on the call-up of qualified engineers and this was published.

The Committee was asked by the Society's Future Policy Committee to prepare a note on the future aims of the Society. This matter was thoroughly considered over a period of several months. A note has been sent to the

MEMBERSHIP AT 31st DECEMBER 1957

Grade	London Register	Australian Division	Southern Africa Division	New Zealand Division	Life and Honorary	Totals	Suspended London Register Members (Included in the foregoing figures)	1957 Elected Members not yet paid (Included in the foregoing figures)
Fellows ..	434 (407)	15 (14)	3 (3)	4 (4)	(H) 30 (L) 18 (47)	504 (475)	3	—
Associate Fellows ..	4042 (3728)	155 (139)	55 (57)	34 (33)	(L) 18 (18)	4304 (3975)	83	10
Associates ..	2119 (2020)	77 (73)	89 (82)	66 (62)	(L) 5 (5)	2356 (2242)	84	8
Graduates ..	1186 (1213)	55 (56)	5 (5)	5 (7)	— (—)	1251 (1281)	44	6
Students ..	1222 (1016)	48 (42)	5 (7)	5 (6)	— (—)	1280 (1071)	72	46
Founder Members ..	12 (12)	— (—)	— (—)	— (—)	(L) 1 (1)	13 (13)	—	—
Companions ..	163 (155)	10 (9)	5 (7)	3 (4)	(H) 4 (L) 7 (10)	192 (185)	4	4
Temporary Honorary Members ..	— (—)	— (—)	— (—)	— (—)	— 53 (53)	53 (53)	—	—
	9178 (8551)	360 (333)	162 (161)	117 (116)	(H) 34 (L) 102 (134)	9953 (9295)	290 (253)	74

Figures in brackets are corresponding figures at 31st December 1956

Future Policy Committee suggesting several ways in which the status of the Society and of the aeronautical engineering profession might be enhanced. The Committee hopes that these views will receive serious consideration; no less that 25 per cent of the Society's members are Graduates and Students.

Finally, the Committee would like to thank all those who have given lectures and have arranged visits on its behalf. Thanks are also due to the members of the Society's staff who have so greatly helped the Committee in its work.

Visits

1957
- 20th March: D. Napier and Son Ltd.
- 30th May: Bristol Aircraft Ltd.
- 10th July: R.A.E. Rocket Propulsion Department, Westcott.
- 17th August: Atomic Energy Research Establishment, Harwell.
- 17th December: Road Research Laboratory.

1958
- 11th January: Vickers-Armstrongs (Aircraft) Ltd., Weybridge.
- 1st February: Guinness Brewery, Park Royal
- 28th February: Lotus Engineering Co.

Lectures

1957
- 5th March: Annual General Meeting and Film Show.
- 19th March: Gas Turbines for Helicopters by A. W. Morley.
- 17th April: Problems and Prospects in Air Transport by P. G. Masefield.
- 15th May: Guided Weapon Research and Development by W. H. Stephens.
- 26th September: The Future of the Royal Air Force by C. I. Orr-Ewing.
- 16th October: Trends in Air Transport by P. W. Brooks.
- 7th November: Film Show in place of The Background to Aircraft Specifications by K. W. Clark, which was cancelled owing to security.
- 27th November: Flight Testing Procedures at Supersonic Speeds by Wing Cdr. R. P. Beamont.
- 10th December: Film Show.

1958
- 28th January: Developments in Glider Design by K. G. Wilkinson.

Medals and Awards of the Society

Full particulars of the Medals and Awards of the Society were published in the June and July 1957 Journals.

Honorary Fellow

The Council has pleasure in recording that HIS ROYAL HIGHNESS THE PRINCE OF THE NETHERLANDS honoured the Society by accepting Honorary Fellowship.

Honorary Companion

The Council has pleasure in recording also that the following has been accorded the honour of Honorary Companionship of the Society:—

MISS BETTY VOYCE.

The Scrolls of Honorary Membership were presented at the 45th Wilbur Wright Memorial Lecture on 13th September 1957, H.R.H. The Prince of the Netherlands being present.

ROYAL AERONAUTICAL SOCIETY PRIZES IN AERONAUTICS

The following Royal Aeronautical Society Prizes in Aeronautics for 1957 have been awarded by the Council. The Society's Prizes in Aeronautics are awarded to the best Student in the Aeronautical Department in each case.

University of Bristol: D. N. Foster
Cambridge University: P. Bradshaw
Imperial College of Science and Technology: Suresh Bhagat
Queen Mary College: J. T. Everest
College of Aeronautics: Lt. Hartland and A. Gray
Glasgow University: David A. Pirie
University of Southampton: Tudor Sprinks
Northampton College of Technology: B. J. Edwards

SCHOLARSHIPS

The Edward Busk Studentship in Aeronautics: Mr. D. J. Maull of Guildford.

The Geoffrey de Havilland Memorial Scholarship: Mr. J. Counihan of Kingston-on-Thames.

GRANTS FROM THE EDUCATION FUND

Grants in aid of further study and research in aeronautics have been awarded to the following:—

A. L. Yettram
G. E. Cook
T. J. Black
J. I. Dodds
I. M. Allison

ELLIOTT MEMORIAL PRIZE

The Elliott Memorial Prize presented to the Apprentice receiving the highest marks in the General Studies Examination at Halton R.A.F. Station has been awarded to the following:—

Sergeant D. W. Bridger
Sergeant W. J. Woolridge
Sergeant Apprentice J. C. Collier

BADEN-POWELL MEMORIAL PRIZE

The Baden-Powell Memorial Prize, awarded to the best candidate in Part II of the December 1957 Associate Fellowship Examination, has been awarded to Mr. R. E. Taylor.

Honours Awarded to Members

Members of the Society have been honoured by Her Majesty the Queen during the year. These the Council have much pleasure in congratulating.

Other Honours have been conferred upon Members of the Society by learned Societies and other bodies; the Council also congratulates these Members.

BIRTHDAY HONOURS LIST 1957

Commander of the Order of the British Empire
Mr. J. Wright (*Fellow*)

Officer of the Order of the British Empire
Captain B. C. Frost (*Associate Fellow*)
Mr. R. A. Shaw (*Associate Fellow*)
Mr. L. P. Twiss (*Associate Fellow*)
Mr. V. H. Wilton (*Associate Fellow*)

Member of the Order of the British Empire
Mr. A. F. Houlberg (*Associate Fellow*)

NEW YEAR'S HONOURS LIST

Knight Bachelor
Mr. G. J. R. L. D'Erlanger (*Associate*)

Knight Commander of the Bath
Air Vice-Marshal A. W. B. McDonald (*Associate Fellow*)

Commander of the Bath
Mr. Hayne Constant (*Fellow*)
Mr. J. E. Serby (*Fellow*)

Commander of the British Empire
Captain V. A. M. Hunt (*Fellow*)
Mr. W. A. Summers (*Fellow*)

Officer of the British Empire
Mr. L. R. E. Appleton (*Fellow*)
Mr. A. D. Balmain (*Associate Fellow*)
Mr. R. G. Fall (*Associate Fellow*)
Mr. I. B. Fleming (*Fellow*)
Captain R. P. Mollard (*Associate Fellow*)
Mr. E. J. Richards (*Fellow*)
Mr. J. L. Watkins (*Fellow*)
Wing Commander F. J. French (*Associate*)

OTHER HONOURS AWARDED TO MEMBERS

The National Advisory Committee for Aeronautics have awarded their Distinguished Service Medal to Dr. Jerome C. Hunsaker (*Honorary Fellow*) "for service of fundamental significance to aeronautical science, climaxed by an outstanding and unparalleled record of leadership during the past fifteen years."

The Institute of the Aeronautical Sciences elected Mr. Bo. K. Lundberg (*Fellow*) an Honorary Fellow.

Air Commodore Sir Frank Whittle (*Honorary Fellow*) was awarded the John Scott Award of America. The Award has been made to such outstanding people as Orville Wright, Thomas Edison, Madame Curie, Guglielmo Marconi, Sir Alexander Fleming and Igor Sikorsky.

The International Society of Aviation Writers elected as their first Honorary Member Dr. E. P. Warner (*Honorary Fellow*).

Professor H. B. Squire (*Fellow*) was elected a Fellow of the Royal Society.

Journal Premium Awards

The Council announce that it has been decided to discontinue the practice of awarding premiums for papers published in the Journal.

Finance

The Income and Expenditure Accounts and Balance Sheets of The Royal Aeronautical Society and the Aeronautical Trusts Limited for 1957 are published with this Report.

Officers and Committees

The Council has been very well served over the year by the hard-working Members of the Committees of the Society. The work of some of the Committees is arduous and entails the Members giving up much of their own time. The Council is grateful to them.

Technical

Ensuring that at least a part of the ever increasing flood of aeronautical research data was properly correlated and incorporated into consistent design and analytical procedures was again the main task of the Society's Technical Department during 1957. Some idea of the extent to which this was achieved may be obtained from the issues made of new and revised data sheets and the extent of the new sheets prepared during the year.

Twenty-two new Structures Data Sheets were circulated to subscribers and a further nine were completed for circulation at a later date. Ten new Aerodynamics Data Sheets, each consisting of up to ten pages were issued at the end of 1957. The continuing increased demands for work completed under previous years meant that some ninety sheets in the Structures and Aerodynamics series had to be scrutinised and redrawn for reprinting. The changes in emphasis in the aeronautical scene are apparent, from the problems covered in the new sheets. They included supersonic wave drag of wings at zero lift, rolling moment due to rolling at supersonic speeds of wings, wing-body combinations, cruciform wing configurations and normal forces on bodies of revolution at supersonic speeds in the Aerodynamics series. In the Structures series the coverage given to members subjected to combined bending and axial loading, the extension of the data on stress concentrations and the buckling of sandwich panels similarly reflects current interest in design problems associated with missiles and high speed civil aircraft.

Other problems of current interest have not been overlooked, although data sheets were not issued on them during 1957. Work on Performance recommenced during the year and work began on a range of topics including turning performance, optimum climb techniques, estimation of lift-dependent drag in incompressible flow, take-off and landing distance and intake efficiency. A re-evaluation of the situation on structural fatigue, made at the end of 1956, resulted in the preparation during 1957 of a first group of data sheets, and brought them near to the stage of completion. These Fatigue Data Sheets are of three distinct types (*a*) those which bring some order into matters of notation, definition and statistical analysis, (*b*) those which are of an educational nature being collected experience on such matters as detail design, and (*c*) those which give data and establish analytical procedures for such topics as atmospheric gusts, joints and complete structural assemblies.

The increasing complexity of some of the subjects has meant that there is a change taking place in the method of attack being adopted by the Technical Department. That the style of data sheets produced is changing has already been noted, with particular reference to the number of pages which one sheet may comprise. There have been, however, other changes taking place, notably along the lines of ensuring that the work in progress is reported to the Society's Members at a stage earlier than may be possible in completed data sheet form and in the presentation of information where data sheet form is not appropriate. The preparation of two bibliographies classified by subject was commenced during 1957, based on the extensive literature searches which are the first step in data sheet development; these will be ready for issue during 1958. The summary of certain technical meetings of The Advisory Group on Aeronautical Research and Development of N.A.T.O. has also been undertaken during the year and three comprehensive accounts were produced primarily for the Technical Committees and various technical contacts among the Society's Membership.

Materials data has had the full attention of a group of the Technical Department during the year. The problem of producing consistent and reasonably complete information on aircraft Materials is not one which it was thought could be solved through the medium of the conventional Data Sheets of the Society. An outlet for such an activity was formed by A.G.A.R.D. and the work which is being produced will in due course be published in A.G.A.R.D. Manual form.

The success of the Society's technical activities is undoubtedly a function of the particular arrangement of expert Technical Committees having the support of a fully qualified and experienced staff. These Committees are now constituted as follows:—

TECHNICAL COMMITTEES

Structures Committee

Mr. H. B. Howard (*Chairman*)
Mr. H. L. Cox
Professor W. S. Hemp
Mr. D. James
Mr. E. D. Keen
Mr. E. Loveless
Dr. E. H. Mansfield
Mr. F. Tyson

Aerodynamics Committee

Professor A. D. Young (*Chairman*)
Mr. R. Dickson
Mr. J. W. Fozard
Dr. D. W. Holder
Mr. R. Melling
Mr. J. D. Poole
Mr. R. A. Shaw
Mr. J. C. Stevenson
Mr. H. H. B. M. Thomas
Mr. A. K. Weaver

Performance Committee

Mr. R. H. Whitby (*Chairman*)	Mr. S. R. Hughes
Mr. J. R. Collingbourne	Mr. C. F. Toms
Mr. R. P. Dickinson	Mr. A. H. Yates

Fatigue Committee

Mr. H. L. Cox (*Chairman*)	Mr. H. B. Howard
Mr. R. J. Atkinson	Mr. N. H. Mason
Mr. G. Forrest	Mr. R. H. Sandifer
Mr. H. Giddings	Mr. W. Tye

In addition to the work referred to above the Technical Department have taken part in a number of assignments on behalf of the Society. The largest commitments of this type during the year were in connection with the Sixth Anglo-American Aeronautical Conference reported in full elsewhere. A whole day joint meeting with The Institute of Physics on non-destructive testing was organised by the Technical Staff and they have also acted on the Society's behalf at various meetings of other bodies. In this last respect the Head of the Department, Anthony J. Barrett, was appointed as one of the three United Kingdom Members of the Structures and Materials Panel of A.G.A.R.D.

Donations

Donations have been received during 1957 from the following: —

Blackburn and General Aircraft Corporation Limited
Bristol Aeroplane Company Limited
de Havilland Holdings Limited
Dowty Equipment Limited
English Electric Group
Folland Aircraft Limited
Hawker Siddeley Group
Hunting Aircraft Limited
Ministry of Supply
Rolls-Royce Limited
Society of British Aircraft Constructors
Vickers-Armstrongs (Aircraft) Limited
Westland Aircraft Limited

The Society has also received grants for Technical Work from: —

The Society of British Aircraft Constructors
The Ministry of Supply

Library

It would seem that the peak figure for loans has yet to be reached.

The figure for 1957 (1,417) shows an increase of 320 over that for 1956. The number of acquisitions to the Library was exactly the same as that for the previous year (337). Review copies (145) showed a drop of 52, while bought items (92) increased by 12.

Inquiries by telephone and post have again increased, but there are, unfortunately, no figures from which to draw comparisons.

As a result of a paragraph in an evening paper, a few interesting relics were presented by people who had no connection with the Society but who appreciated the value of a permanent home for such items (*see* pp. XXXIII May, XI June, XXVI July, IX October 1957 Journals).

Members have also contributed old books, photographs, and so on, all of which are most welcome.

There is still a good demand for lantern slides despite more modern developments and manufacturers have been most co-operative in providing slides of their machines in response to requests.

Publications

The past year has been a particularly busy one; in addition to the normal miscellaneous printing required for the ever increasing activities of the Society, such as the Air Transport Course, the Anglo-American Conference in September followed by the Garden Party, meant much extra printing apart from the advance copies of the Conference papers. Also, the Society was responsible for publishing the papers given at the Joint High Altitude and Satellite Rocket Symposium held at Cranfield in July.

The Society is indeed well served by its printers who, for more than 30 years, have given invaluable service and maintained their high standards.

The Proceedings of the Sixth Anglo-American Conference and of the Joint Symposium are now in hand and it is hoped that both volumes will be published by the middle of the year.

The circulation of the JOURNAL has risen steadily and by 1st March 1958 the number of copies printed was 11,200 a month. Although this increase is again mainly attributable to the growing membership of the Society, outside subscriptions and sales have also increased. There are now over 1,200 annual subscriptions to the Journal from all over the world, including Russia, and it is said that the Journal is one of the most widely quoted there, both the papers and the Reports.

More Branch Lectures were published in 1957 and more papers, but the amount of material received for publication has increased greatly and the time lag between acceptance and the publication of papers is, unfortunately, growing and is a matter of some concern. An indication of the mounting volume of aeronautical material published is the greater number of pages in the Journal devoted to summaries of Reports received by the Library. Twenty-eight per cent more pages have been allocated to Reports in the Journal in 1957 and eleven per cent more to Reviews. It is felt that the publication of summaries of these Reports is of some value to members. As from January 1958 brief descriptions are being given of all the Additions to the Library listed each month and only the more important books directly applicable to aeronautics are being reviewed at length. This should mean earlier publication of reviews. Members' comments on the value of the Reports' Section and this new treatment of "Additions" and, indeed, any suggestions for the Journal, would be welcomed.

The Lectures of the Guided Flight Section are also being published in the Journal and the first lecture was in the March 1958 issue. Reprints of these papers will be available at 7s. 6d. each.

The increase in the volume of the AERONAUTICAL QUARTERLY in 1957 has brought more improvement in its position and sales have increased significantly. The time lag between receipt and publication of a paper has now been reduced to less than a year and is comparable with similar publications. The Editorial Board is anxious to widen still further the range of subjects covered and to dispel any idea that papers published in the Quarterly must be highly mathematical. The requirements are for papers describing original work usually on a specialised subject, and the Society would be pleased to receive such papers on aircraft propulsion, including intakes and noise problems, and on materials for aircraft and engines.

Invaluable work is done by the referees of the Quarterly in assessing papers and very often in suggesting improvements. To them must go a large part of the credit for maintaining the high standard of the papers published.

"Recruitment pages" were introduced in the Quarterly in 1957 and these were a great help financially, so that the Quarterly has been increased in size without additional cost to the Society or to readers. These pages have been used by the leading aircraft firms to bring their activities to the notice of readers and to indicate the fields of science and technology where they have openings for graduates.

Three BOOKS have been published on behalf of the Society during the year; a monograph by Mr. C. N. Jacques "Instrumentation in Testing Aircraft," the second volume of the "Aircraft Hydraulics" textbooks and, very recently, "Landing Gear Design" by Mr. H. G. Conway. A book "Aircraft Electrical Engineering" is with the publishers and a Bibliography on Fatigue is in preparation. A working party has just been formed to arrange the preparation of a book on full-scale layout and sheet metal design. All books are selling steadily, and the sales of the first two textbooks are especially encouraging.

THE ROYAL

(INCORPORATED

BALANCE SHEET

1956 Figures £		£ s. d.	£ s. d.	£ s. d.
	CURRENT LIABILITIES			
6337	Sundry Creditors		8296 15 0	
5101	Subscriptions and other amounts received in advance		5022 3 11	
				13318 18 11
	SURPLUS (subject to depreciation of Investments)			
	Reserve for Conferences and Courses			
	Balance at 31st December 1956		2909 6 6	
	Add transfer from Income and Expenditure Account		1500 0 0	
			4409 6 6	
	Deduct Expenditure less receipts during year		1596 7 5	
2909			2812 19 1	
	Income and Expenditure Account			
	Balance at 31st December 1956	17030 13 6		
	Add Surplus of Income over Expenditure for year to date	1249 17 4		
			18280 10 10	
17031				21093 9 11
£31378				£34412 8 10

G. R. EDWARDS
President.

G. P. BULMAN
Honorary Treasurer.

REPORT OF THE AUDITORS TO THE MEMBERS

In our opinion the above balance sheet and the annexed income and Society Endowment Fund included in the annexed accounts of Aeronautical Trusts Ltd., and of its surplus for the year ended on that date.

We have obtained all the information and explanations which we considered in agreement with them and the said information and explanations.

3 Frederick's Place, Old Jewry, London, E.C.2.
24th March 1958.

AERONAUTICAL SOCIETY

BY ROYAL CHARTER 1949)

31st DECEMBER 1957

1956 Figures £		£ s. d.	£ s. d.
	CURRENT ASSETS		
1	Stock of Journals and other publications	1 0 0	
11522	Sundry debtors and payments in advance	15693 1 1	
8607	Balances at Bank and Cash in Hand	7029 10 9	
			22723 11 10
5600	**INVESTMENTS AT COST**		5600 0 0
	Market value 31st December 1957 £4,175 (1956 £4,354)		
	AERONAUTICAL TRUSTS LIMITED		
1	21 shares of 1/- each fully paid at cost	1 1 0	
253	Amounts due on current account	682 16 0	
			683 17 0
	PRINTED BOOKS, BINDINGS, OLD PRINTS, ETC.		
50	At nominal amount		50 0 0
	COLLECTION OF HISTORICAL AIRCRAFT (including Nash Collection)		
5344	At cost		5355 0 0
£31378			£34412 8 10

OF THE ROYAL AERONAUTICAL SOCIETY

expenditure account of the Society, together with the accounts of the Royal Aeronautical give a true and fair view of the state of the Society's affairs as at 31st December 1957,

necessary. In our opinion the Society has kept proper books, and the said accounts are

(*Signed*) PRICE WATERHOUSE & CO.

THE ROYAL

INCOME AND EXPENDITURE ACCOUNT

1956 Figures £			£ s. d.	£ s. d.
		ESTABLISHMENT EXPENSES		
2975		Ground Rent, Heating, Lighting, Insurance and Repairs		2882 11 4
		ADMINISTRATIVE AND OFFICE EXPENSES		
12911		Salaries and National Insurance	13293 19 7	
1645		Pension and Pension Premiums	1333 13 7	
2754		Printing and Stationery	2739 19 0	
2052		Postages and Telephones	1977 0 3	
404		Office Furniture and Equipment	485 19 7	
454		Travelling Expenses	321 11 5	
845		Other Charges	485 17 9	
	21065			20638 1 2
		JOURNAL AND PUBLICATIONS		
4325		Salaries and Pension Premiums	4658 4 7	
20500		Printing	21275 6 5	
—		Printing Year Book	675 15 7	
3260		Postages and Wrappers	3409 4 8	
1399		Other Expenses	1092 18 1	
	29484			31111 9 4
		TECHNICAL COMMITTEES		
6661		Salaries and Pension Premiums	6890 8 0	
3997		Printing and other charges	4632 0 4	
135		Travelling Expenses	186 14 7	
	10793			11709 2 11
		GARDEN PARTY		
2332		Expenses		2477 2 0
541		EXAMINATIONS EXPENSES		745 0 6
647		MEETINGS		702 18 0
1500		RESERVE FOR CONFERENCES AND COURSES		1500 0 0
678		DINNERS AND RECEPTIONS		611 17 6
		LIBRARY		
1688		Salaries and Pension Premiums	1335 5 5	
378		Expenses	622 8 8	
	2066			1957 14 1
565		GRANTS TO BRANCHES AND SECTIONS		605 0 0
249		PRIZES AND AWARDS		269 4 6
300		CHARTER SCHOLARSHIPS		300 0 0
289		LEGAL AND PROFESSIONAL CHARGES		870 0 0
367		PAYMENT TO CANADIAN AERONAUTICAL INSTITUTE		371 16 4
1898		BALANCE, BEING SURPLUS OF INCOME OVER EXPENDITURE FOR YEAR, CARRIED TO BALANCE SHEET		1249 17 4
£75749				£78001 15 0

AERONAUTICAL SOCIETY

FOR THE YEAR ENDED 31st DECEMBER 1957

1956 Figures £			£ s. d.	£ s. d.
27771		ANNUAL SUBSCRIPTIONS		29530 13 0
10861		DONATIONS AND GRANTS		11010 17 7
168		INTEREST ON INVESTMENTS (GROSS)	168 0 0	
226		INTEREST ON DEPOSIT ACCOUNT AT BANK	248 0 5	
5425		SURPLUS ON ENDOWMENT FUND INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR	5465 12 2	
	5819			5881 12 7
		JOURNAL AND PUBLICATIONS		
15586		Advertising Revenue	14451 13 0	
9007		Sales	10967 1 10	
	24593			25418 14 10
		TECHNICAL COMMITTEES		
3728		Sales		3618 10 6
		GARDEN PARTY		
1888		Sale of Tickets	1649 8 6	
599		Profit on Programme	372 6 6	
	2487			2021 15 0
490		EXAMINATIONS FEES		519 11 6
£75749				£78001 15 0

BALANCE SHEET

1956 Figures £		£ s. d.	£ s. d.
	SHARE CAPITAL		
	AUTHORISED: 40 shares of 1s. each	2 0 0	
1	ISSUED: 21 shares of 1s. each fully paid		1 1 0
	ROYAL AERONAUTICAL SOCIETY ENDOWMENT FUND		
	CAPITAL ACCOUNT		
135223	Balance at 31st December 1956	136566 11 8	
1131	*Add* Entrance Fees received during year	1253 3 0	
213	Donations received during year	1 1 0	
136567		137820 15 8	
	INCOME ACCOUNT		
9104	Balance as at 31st December 1956	9103 14 6	
145671			146924 10 2
	ROYAL AERONAUTICAL SOCIETY EDUCATION FUND		
	INCOME ACCOUNT		
—	Balance at 31st December 1956	484 13 9	
485	*Add* Surplus of Income over Expenditure for year to date ..	39 3 2	
485			523 16 11
	EDWARD BUSK STUDENTSHIP IN AERONAUTICS		
	CAPITAL ACCOUNT		
5423	Balance as at 31st December 1956		5423 10 4
£151580	*Forward*		£152872 18 5

TRUSTS LIMITED

31st DECEMBER 1957

1956 Figures £		£ s. d.	£ s. d.	£ s. d.
1	CASH IN HAND			1 1 0
	ROYAL AERONAUTICAL SOCIETY ENDOWMENT FUND			
	Leasehold Property at cost *less* amounts written off			
	4, 8 and 9 Hamilton Place			
	At cost	14185 1 9		
	Less Amortisation written off to date	10401 1 9		
4439			3784 0 0	
	Furniture at cost *less* depreciation			
	At cost	6396 1 11		
	Less Depreciation written off to date	4544 1 11		
2172			1852 0 0	
133859	Investments at cost		134232 6 11	
	Market value 31st December 1957 £100,303 (1956 £106,914)			
			139868 6 11	
	Current Assets			
375	Sundry Debtors	1301 12 4		
4854	Balance at bank	6254 16 11		
			7556 9 3	
145699			147424 16 2	
28	*Less* Amount due to the Royal Aeronautical Society		500 6 0	
145671				146924 10 2
	ROYAL AERONAUTICAL SOCIETY EDUCATION FUND			
—	Investment at cost		391 13 3	
	Market value 31st December 1957 £395			
250	Amount due from Edward Busk Studentship in Aeronautics		24 4 9	
121	Amount due from Geoffrey de Havilland Memorial Fund		— — —	
339	Balance at Bank		107 18 11	
710			523 16 11	
225	*Less Amount due to Royal Aeronautical Society*		— — —	
485				523 16 11
	EDWARD BUSK STUDENTSHIP IN AERONAUTICS			
	Investments at valuation 31st December 1951		4806 10 0	
	Investments at cost		601 6 6	
5408			5407 16 6	
	Market value 31st December 1957 £4,435 (1956 £4,890)			
265	Balance at Bank		39 18 7	
5673			5447 15 1	
250	*Less* Amount due to Royal Aeronautical Society		24 4 9	
5423				5423 10 4
£151580	*Forward*			£152872 18 5

BALANCE SHEET—*Continued*

1956 Figures £		£ s. d.	£ s. d.	£ s. d.
151580	*Forward*			152872 18 5
	GEOFFREY DE HAVILLAND MEMORIAL FUND			
	CAPITAL ACCOUNT			
	Balance at 31st December 1956		4175 17 5	
4176	*Add* Donations received during year		40 0 0	
				4215 17 5
	WILBUR WRIGHT MEMORIAL FUND			
	CAPITAL ACCOUNT			
2212	As at 31st December 1956		2211 17 11	
	INCOME ACCOUNT			
174	Balance at 31st December 1956	155 0 10		
(–19)	*Less* Excess of Expenditure over Income for year to date	19 1 8	135 19 2	
2367				2347 17 1
	EDWARD BUSK MEMORIAL FUND			
	CAPITAL ACCOUNT			
449	As at 31st December 1956		449 6 1	
	INCOME ACCOUNT			
250	Balance at 31st December 1956	253 6 7		
3	*Add* Surplus of Income over Expenditure for the year to date	3 10 4		
			256 16 11	
702				706 3 0
	PILCHER MEMORIAL FUND			
	CAPITAL ACCOUNT			
100	As at 31st December 1956		99 14 0	
	INCOME ACCOUNT			
80	Balance at 31st December 1956	75 3 4		
(–5)	*Add* Income for year to date	5 7 4		
			80 10 8	
175				180 4 8
	USBORNE MEMORIAL FUND			
	CAPITAL ACCOUNT			
109	As at 31st December 1956		109 2 5	
	INCOME ACCOUNT			
81	Balance at 31st December 1956	76 3 0		
(–5)	*Less* Excess of Expenditure over Income for year to date	4 10 8	71 12 4	
185				180 14 9
	HERBERT AKROYD STUART FUND			
	CAPITAL ACCOUNT			
691	As at 31st December 1956		691 9 0	
	INCOME ACCOUNT			
703	Balance at 31st December 1956	726 17 4		
24	*Add* Surplus of Income over Expenditure for year to date	24 0 6	750 17 10	
1418				1442 6 10
£160603	*Forward*			£161946 2 2

TRUSTS LIMITED

31st DECEMBER 1957

1956 Figures £		£ s. d.	£ s. d.
151580	*Forward*		152872 18 5
	GEOFFREY DE HAVILLAND MEMORIAL FUND		
4176	Investment at cost	4175 17 5	
	Market value 31st December 1957 £2,851 (1956 £3,013)		
121	Balance at Bank	40 0 0	
4297		4215 17 5	
121	*Less Amount due to Royal Aeronautical Society Education Fund* ..	— — —	
4176			4215 17 5
	WILBUR WRIGHT MEMORIAL FUND		
2251	Investments at cost	2250 14 9	
	Market value 31st December 1957 £1,662 (1956 £1,980)		
116	Balance at Bank	197 2 4	
2367		2447 17 1	
—	*Less* Amount due to the Royal Aeronautical Society	100 0 0	
2367			2347 17 1
	EDWARD BUSK MEMORIAL FUND		
658	Investments at cost	658 8 8	
	Market value 31st December 1957 £461 (1956 £517)		
44	Balance at Bank	68 14 4	
702		727 3 0	
—	*Less* Amount due to the Royal Aeronautical Society	21 0 0	
702			706 3 0
	PILCHER MEMORIAL FUND		
156	Investment at cost	156 5 0	
	Market value 31st December 1957 £97 (1956 £108)		
19	Balance at Bank	23 19 8	
175			180 4 8
	USBORNE MEMORIAL FUND		
175	Investment at cost	174 11 1	
	Market value 31st December 1957 £109 (1956 £121)		
10	Balance at Bank	16 13 8	
185		191 4 9	
—	*Less* Amount due to the Royal Aeronautical Society	10 10 0	
185			180 14 9
	HERBERT AKROYD STUART FUND		
1278	Investments at cost	1278 11 1	
	Market value 31st December 1957 £822 (1956 £910)		
140	Balance at Bank	184 15 9	
1418		1463 6 10	
—	*Less* Amount due to the Royal Aeronautical Society	21 0 0	
1418			1442 6 10
£160603	*Forward*		£161946 2 2

BALANCE SHEET—*Continued*

1956 Figures £		£ s. d.	£ s. d.	£ s. d.
160603	*Forward*			161946 2 2
	R.38 MEMORIAL FUND			
	CAPITAL ACCOUNT			
982	As at 31st December 1956		981 13 10	
	INCOME ACCOUNT			
1147	Balance at 31st December 1956	1217 2 5		
70	*Add* Income for year to date	69 11 8	1286 14 1	
2199				2268 7 11
	SIMMS GOLD MEDAL FUND			
	CAPITAL ACCOUNT			
528	As at 31st December 1956		527 15 9	
	INCOME ACCOUNT			
121	Balance at 31st December 1956	134 12 11		
13	*Less* Excess of Expenditure over Income for year to date	4 8	134 8 3	
662				662 4 0
	ALSTON MEMORIAL FUND			
	CAPITAL ACCOUNT			
250	As at 31st December 1956		250 8 10	
	INCOME ACCOUNT			
85	Balance at 31st December 1956	86 7 7		
1	*Add* Surplus of Income over Expenditure for year to date	1 3 0	87 10 7	
336				337 19 5
£163800				£165214 13 6

REPORT OF THE AUDITORS TO THE

In our opinion the foregoing accounts give a true and fair view of the state and of the surplus of the Funds for the year ended on that date.

We have obtained all the information and explanations which we considered which are in agreement with them and with the said information and explanations, give

3 Frederick's Place, Old Jewry, London, E.C.2.
24th March 1958.

TRUSTS LIMITED

31st DECEMBER 1957

1956 Figures £		£ s. d.	£ s. d.
160603	*Forward*		161946 2 2
	R.38 MEMORIAL FUND		
2005	Investments at cost .. .. 2004 18 9 Market value 31st December 1957 £1,269 (1956 £1,407)		
194	Balance at Bank 263 9 2		
2199			2268 7 11
	SIMMS GOLD MEDAL FUND		
585	Investments at cost .. .. 585 0 0 Market value 31st December 1957 £404 (1956 £436)		
77	Balance at Bank 97 4 0		
662		682 4 0	
—	*Less* Amount due to the Royal Aeronautical Society 20 0 0		
662			662 4 0
	ALSTON MEMORIAL FUND		
295	Investment at cost .. .. 295 2 10 Market value 31st December 1957 £201 (1956 £225)		
41	Balance at Bank 52 16 7		
336		347 19 5	
—	*Less* Amount due to the Royal Aeronautical Society 10 0 0		
336			337 19 5
£163800			£165214 13 6

MEMBERS OF AERONAUTICAL TRUSTS LTD.

of the Company's affairs and of the Funds administered by it as at 31st December 1957,

necessary. In our opinion the Company has kept proper books, and the said accounts, in the prescribed manner the information required by the Companies Act, 1948.

(*Signed*) PRICE WATERHOUSE & CO.

AERONAUTICAL

INCOME AND EXPENDITURE ACCOUNTS

ROYAL AERONAUTICAL SOCIETY

1956 Figures £		£ s. d.
655	Amortisation of Leasehold Property	655 0 0
320	Depreciation of Furniture	320 0 0
8	Legal Expenses	10 10 0
5426	Surplus of Income over Expenditure for year, transferred to the Royal Aeronautical Society	5465 12 2
£6409		£6451 2 2

ROYAL AERONAUTICAL SOCIETY

£		£ s. d.
826	Grants made in 1957	607 10 0
485	Surplus of Income over Expenditure for year, carried to Balance Sheet	39 3 2
£1311		£646 13 2

EDWARD BUSK STUDENTSHIP

£		£ s. d.
250	Transfer to Royal Aeronautical Society Education Fund	225 7 0
£250		£225 7 0

GEOFFREY DE HAVILLAND

£		£ s. d.
106	Transfer to Royal Aeronautical Society Education Fund	121 6 2
15	*Loss on sale of investment*	— — —
£121		£121 6 2

WILBUR WRIGHT

£		£ s. d.
100	1957 Award	100 0 0
£100		£100 0 0

EDWARD BUSK

£		£ s. d.
21	1957 Award	21 0 0
3	Surplus of Income over Expenditure for year, carried to Balance Sheet	3 10 4
£24		£24 10 4

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER 1957

ENDOWMENT FUND

1956 Figures £		£ s. d.
2617	Interest on Investments (Gross)	2617 1 4
1357	Interest on Investments (*less* tax)	1407 8 6
935	Refund of Income Tax	926 12 4
1500	Rents Receivable	1500 0 0
£6409		£6451 2 2

EDUCATION FUND

£		£ s. d.
300	Contribution from Royal Aeronautical Society (Charter Scholarship)	300 0 0
543	Transfer from Edward Busk Studentship in Aeronautics	225 7 0
468	Transfer from Geoffrey de Havilland Memorial Fund	121 6 2
£1311		£646 13 2

IN AERONAUTICS

£		£ s. d.
250	Interest on Investments (Gross)	225 7 0
£250		£225 7 0

MEMORIAL FUND

£		£ s. d.
121	Interest on Investment (Gross)	121 6 2
£121		£121 6 2

MEMORIAL FUND

£		£ s. d.
81	Interest on Investments (Gross)	80 18 4
19	Excess of Expenditure over Income for year, carried to Balance Sheet	19 1 8
£100		£100 0 0

MEMORIAL FUND

£		£ s. d.
24	Interest on Investments (Gross)	24 10 4
£24		£24 10 4

AERONAUTICAL

INCOME AND EXPENDITURE ACCOUNTS

PILCHER

1956 Figures £		£ s. d.
—	Income for year, carried to Balance Sheet	5 7 4
10	1957 Award	— — —
£10		£5 7 4

USBORNE

£		£ s. d.
10	1957 Award	10 10 0
£10		£10 10 0

HERBERT AKROYD

£		£ s. d.
21	1957 Award	21 0 0
24	Surplus of Income over Expenditure for year, carried to Balance Sheet	24 0 6
£45		£45 0 6

R.38

£		£ s. d.
70	Income for year, carried to Balance Sheet	69 11 8
£70		£69 11 8

SIMMS GOLD

£		£ s. d.
7	1957 Award	20 0 0
13	*Surplus of Income over Expenditure for year, carried to Balance Sheet*	— — —
£20		£20 0 0

ALSTON

£		£ s. d.
10	1957 Award	10 0 0
1	Surplus of Income over Expenditure for year, carried to Balance Sheet	1 3 0
£11		£11 3 0

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER 1957—*Continued*

MEMORIAL FUND

1956 Figures			
£		£	s. d.
5	Interest on Investment (Gross)	5	7 4
5	*Excess of Expenditure over Income for year*	—	— —
£10		£5	7 4

MEMORIAL FUND

£		£	s. d.
5	Interest on Investment (Gross)	5	19 4
5	Excess of Expenditure over Income for year, carried to Balance Sheet	4	10 8
£10		£10	10 0

STUART FUND

£		£	s. d.
45	Interest on Investments (Gross)	45	0 6
£45		£45	0 6

MEMORIAL FUND

£		£	s. d.
70	Interest on Investments (Gross)	69	11 8
£70		£69	11 8

MEDAL FUND

£		£	s. d.
20	Interest on Investments (Gross)	19	15 4
—	Excess of Expenditure over income for year carried to Balance Sheet		4 8
£20		£20	0 0

MEMORIAL FUND

£		£	s. d.
11	Interest on Investment (Gross)	11	3 0
£11		£11	3 0

International Conference of the Aeronautical Sciences

Mr. E. T. Jones, Past-President of the Society, visited Washington in November 1957 to attend a Committee meeting of the International Conference of the Aeronautical Sciences on behalf of the Society. That meeting resulted in the preparation of a Draft Programme for the first Congress which is to be held in Madrid in September 1958. Particulars for the information of members is published in this April 1958 Journal.

Associate Fellowship Examination

The Associate Fellowship Examinations were held in June and December 1957. The number of candidates at home and abroad in June was 60 and the number in December was 55. The Examination was held in the following countries at the various Universities and Institutions. The Council wishes to thank them for their co-operation.

Australia, Canada, India, Italy, Pakistan, Cyprus, Christmas Island, Holland, B.A.O.R., and South Africa.

A list of those candidates who were successful in the June 1957 examinations was published in the November 1957 Journal and the successful candidates in the December 1957 examinations is published in this April 1958 Journal.

Staff

There have been changes in staff during the year, especially among the junior secretarial staff.

As has already been reported in the Journal, Mr. and Mrs. J. A. Dunsby have gone to Canada. In addition the Accountant, Mr. R. Levinson, has resigned, and he has been replaced by Mr. N. J. A. Deaton, A.C.A., who is already proving his worth.

The Council wish to thank the Secretary and Staff for their work during the past year.

Obituaries

The Council regrets to record the death of the following members of the Society during 1957:—

Sydney Baldwin (*Associate Fellow*)
L. G. Bednell (*Associate Fellow*)
Air Chief Marshal Sir John N. Boothman (*Fellow*)
Captain W. B. Butler (*Associate*)
H. Cantrill (*Fellow*)
Lieutenant F. Creagh-Osborne (*Graduate*)
V. L. Le Cren (*Associate Fellow*)
N. G. N. Davis (*Associate Fellow*)
Group Captain A. H. Fear (*Associate Fellow*)
G. E. Folkes (*Associate Fellow*)
P. J. Ford (*Graduate*)
H. R. Haynes (*Associate Fellow*)
G. D. Huxtable (*Associate Fellow*)
Major C. S. Johnston (*Associate Fellow*)
J. H. P. Jones (*Associate Fellow*)
A. S. R. Lewin (*Associate*)
Vice-Admiral L. D. Mackintosh of Mackintosh (*Associate Fellow*)
Major R. H. Mayo (*Fellow*)
J. W. Munton (*Associate*)
Dr. F. J. Piattelli (*Associate Fellow*)
R. N. Playford (*Associate*)
Wing Commander H. Priestley (*Associate*)
Air Commodore W. H. Primrose (*Associate Fellow*)
A. J. Rowledge (*Fellow*)
R. M. Ryan (*Student*)
Air Vice-Marshal E. W. Stedman (*Fellow*)
I. Tongue (*Associate*)
N. L. Walker (*Associate Fellow*)
F. P. Walsh (*Associate Fellow*)
Squadron Leader M. E. A. Wright (*Fellow*)

TECHNICAL NOTES

The Aerodynamic Drag of Perforated Plates at Zero Incidence

by

P. MINTON and J. R. D. FRANCIS

(Civil Engineering Department, Imperial College, London)

PERFORATED PLATES have been used at large angles of incidence to produce drag forces and evidence on their properties has been published by de Bray[1]. Less appears to be known about the drag forces on such surfaces at zero incidence, although they are usually considered to be aerodynamically rough. This has been confirmed by Ambrose[2], who carried out pipe flow experiments using perforated liners which fitted tightly in the bore of a pipe. Perforated plates used in this way do not allow flow completely through them and give "pitted" surfaces. If a perforated plate is mounted so that it is possible for cross flows to occur between the main flows on *both* sides of the plate the drag forces on it may be affected, and in this case the perforations will be referred to as "holes."

The non-dimensional variables associated with the low speed flow past a perforated plate at zero incidence are:—

(1) the Reynolds number based on the chord of the plate
(2) the Reynolds number based on perforation diameter
(3) the ratio of the area of the perforations to the area of the plate
(4) the ratio of the perforation diameter to the depth of the pit.

TESTS ON PERFORATED PLATES

A series of tests have been performed in the 20 in. × 20 in. low speed tunnel of the Department of Aeronautics, Imperial College, to determine the drag of perforated plates at zero incidence. The plates, which were from 5¾ to 6¼ in. chord, spanned the tunnel and were supported on the walls of the working section. Air speeds of the order of 100 ft./sec. were used, giving a nominal Reynolds number of $3{\cdot}5 \times 10^5$. A Pitot comb was mounted in mid-tunnel approximately one chord downstream of the plate. The Pitot and static pressures were measured with an inclined tube manometer, and the drag computed from the momentum flux in the wake compared with the flux in the approaching stream.

The major experimental difficulty lay in producing plates whose surfaces were flat after the holes had been drilled or punched. The plates were flattened by hand and it is thought that the effect of the remaining waviness was small compared with the roughness of the surfaces.

DESCRIPTION OF PLATES (*See* Table I)

Four plates, *A*, *B*, *C*, *D* (Fig. 1) were made with the area of the perforations 35·5 per cent of the plan area. Each

Received 6th December 1957.

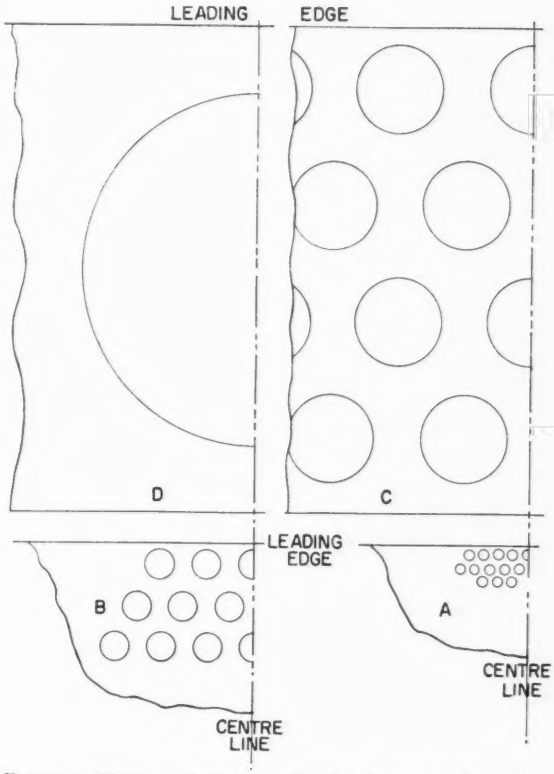

FIGURE 1. Plates *A*, *B*, *C* and *D* showing the perforations about the plate centre line (chain dotted).

TABLE I

DESCRIPTION OF PERFORATED PLATES

Plate	*Hole diameter (in.)*	*No. of spanwise rows*	*Chord (in.)*	*Thickness (in.)*	*Area of holes/ Area of plate*	*Diameter of hole/ Depth of pit*
A	0·125	35	5·85	0·11	0·355	2·3
B	0·375	12	6·25	0·11	0·355	6·8
C	1·125	4	6·25	0·105	0·355	21·6
D	4·5	1	6·25	0·11	0·355	84
E	0·125	9	6·0	0·105	0·089	2·4
F	0·125	35	5·85	0·05	0·355	5·0
G	0·125	9	6·0	0·05	0·089	5·0
H	—	—	6·0	0·105	—	—
I	—	—	6·0	0·05	—	—
J	0·125 (projections)	36	6·25	0·28	0·355	(2·0)

plate consisted of two drilled or punched 18 s.w.g. metal sheets superimposed and fixed together. The perforations were centred on equilateral triangles, but in the case of plate *D* there was only room for one row of $4\frac{1}{2}$ in. diameter perforations. The perforations used gave ratios of diameter to depth of pit from 2·3 to 84.

The drag of each plate was measured twice, first with a sheet of thin paper sandwiched between the two metal sheets, giving "pits" on each side of the plate with a depth of half the plate thickness; and secondly with the paper removed giving "holes" right through the plate.

For comparison, plate *J* was made with a series of cylindrical projections of $\frac{1}{8}$ in. diameter and $\frac{1}{16}$ in. height, the spacing of which was the same as that of the $\frac{1}{8}$ in. diameter pits and holes in plate *A*.

To investigate the effect of the total area of the perforations plate *E* was made with the same diameter perforations as plate *A*, but only one quarter of the number, thus reducing the ratio of punched area to total area to 8·9 per cent. The plates *F* and *G* were made by separating plates *A* and *E* into individual sheets, thus doubling the ratio of hole diameter to plate thickness while keeping the remaining parameters constant.

Two unperforated plates, *H* and *I*, of the same thickness as the perforated plates, were also tested.

COMPARISON OF DRAG COEFFICIENTS (*See* Figure 2)

One of the difficulties associated with finding the skin friction or surface drag of plates of finite thickness lies in separating the total drag into the two components (*a*) the form drag due to the thickness of the plate, and (*b*) the surface drag. An attempt has been made to find the form drag from the result of the experiments on plates *H* and *I*. The skin friction drag for an infinitely thin plate as given by Goldstein[3], has been subtracted from the total drag of these plates and the remainder regarded as the form drag due to their thickness. These values for the form drag have then been subtracted from the total drag of each of the perforated plates to give their surface drags (*see* Table II).

The tests with pits in plates *A*, *B*, *C* and *D* show an increase in surface drag up to twice the smooth plate value in the case of plate *B* with the $\frac{3}{8}$ in. diameter pits. The drag is smaller with both larger and smaller pits. The existence of a maximum value for the surface drag is not unexpected, for with the pit diameter to depth ratio equal to either zero or infinity, the surface drag will be that of a smooth plate.

The surface drag of the plate *J* which has projections on it is approximately twice the surface drag of plate *A* with pits, although it should be remembered that no allowance has been made for the frontal area of the projections. Even if the frontal area of the projections is considered to have the same effect as the frontal area of the plates, the surface drag of the plate with projections will still be greater than the drag of the plate with pits. Tests on similar pits and projections in pipes, by Ambrose[2], have shown comparable results, and it is interesting to note that if the pits are progressively replaced by projections, it is the projections which mainly determine the drag.

On removing the paper forming the bottoms of the pits in plates *A*, *B*, *C* and *D*, the holes connecting the two sides were found to give a greater surface drag than did the pits. The increase in drag was such as to make the drag of plate *A* greater than the drag of plate *J* with projections. The presence of holes allowing flow through the plate must cause a more rapid growth of the boundary layer, and a consequent increase in drag.

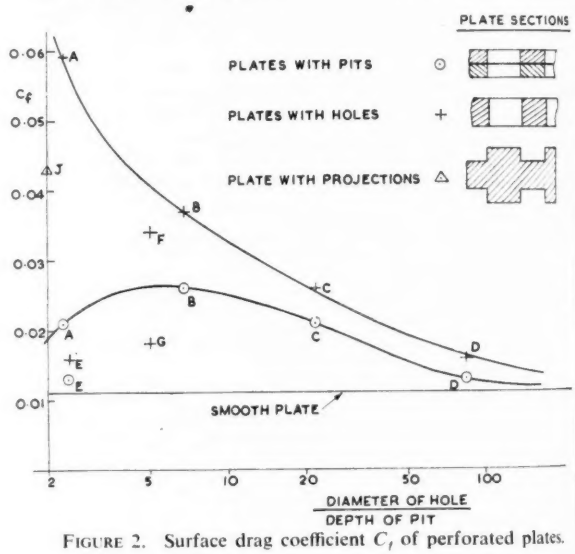

FIGURE 2. Surface drag coefficient C_f of perforated plates.

TABLE II

SURFACE DRAG OF PERFORATED PLATES

Plate	*Plate Reynolds Number*	*Hole Reynolds Number*	*Drag Coefficient*			
			With Pits		*With Holes*	
			As measured	*Corrected for frontal area*	*As measured*	*Corrected for frontal area*
A	$3{\cdot}6\times10^5$	$7{\cdot}7\times10^3$	0·033	0·021	0·071	0·059
B	$3{\cdot}9\times10^5$	$2{\cdot}3\times10^4$	0·038	0·026	0·049	0·037
C	$3{\cdot}6\times10^5$	$6{\cdot}5\times10^4$	0·033	0·021	0·038	0·026
D	$3{\cdot}6\times10^5$	$2{\cdot}6\times10^5$	0·025	0·013	0·028	0·016
E	$3{\cdot}8\times10^5$	$7{\cdot}9\times10^3$	0·025	0·013	0·028	0·016
F	$3{\cdot}7\times10^5$	$7{\cdot}9\times10^3$	—	—	0·038	0·034
G	$3{\cdot}8\times10^5$	$7{\cdot}9\times10^3$	—	—	0·022	0·018
H	$3{\cdot}5\times10^5$	—	0·023	0·011	0·023	0·011
I	$2{\cdot}9\times10^5$	—	0·015	0·011	0·015	0·011
J	$3{\cdot}4\times10^5$	$6{\cdot}8\times10^3$ (projections)	0·055	0·043	—	—

The tests on plate E showed that reducing the number of pits to a quarter of those on plate A produced a proportional decrease in surface drag, but the same reduction in the number of holes gave more than a proportional decrease of drag.

Halving the thickness of plate A to make plate F, gave a decrease in surface drag, presumably due to an increase in the hole diameter/depth ratio. However, with only a quarter of the number of holes of plate A, halving the thickness increased the drag, as shown by the experiments on plates E and G.

It is apparent from the tests that perforated surfaces, particularly those with holes, are surprisingly rough in the aerodynamic sense, the roughness depending on the perforated area and on the diameter to depth ratio of the perforations. Hence surfaces with pits or holes in them may be used at zero incidence when a high dissipation of energy is required with but a small blockage of a flow. Thus, a high speed stream could be decelerated by building longitudinal perforated walls and floors. When perforated surfaces are used for boundary layer suction purposes, it may be advisable to choose hole sizes and spacings that minimise the drag when there is no suction.

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Heat Transfer from Rotating Discs

by

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COEFFICIENTS for heat transfer from free rotating discs, at Reynolds numbers in excess of $4{\cdot}8 \times 10^5$ have recently been obtained by Cobb and Saunders[1]. These results are consistent with a limiting turbulent-flow heat transfer given by:—

$$Nu \text{ mean} = 0{\cdot}0172\, Re^{0{\cdot}80} \quad . \quad . \quad (1)$$

where $Nu = \dfrac{hD}{k}$ (Nusselt number)

$Re = \omega D^2/2\nu$ (Reynolds number)

D outer disc diameter

h heat transfer coefficient

k heat conduction coefficient

ν kinematic viscosity

ω angular velocity

Cobb and Saunders compare their results to values of Nu mean obtained by applying Reynolds' analogy to local friction coefficients, obtained in turn from Von Kármán's value of friction torque on a rotating disc[2]. The latter has been calculated by assuming the 1/7th power law for velocity distribution and has since been found to agree with experimental data. Very good agreement with equation (1) is noted.

A case of practical interest is that of a disc rotating in a casing at high Reynolds numbers. It has been found by Schultz-Grunow[3] and Ribary[4] that the friction torque of such a disc is smaller than that obtained on a free disc with no casing, and that in the turbulent range the width of the air gap has little influence on friction torque at small fluid leakage rates. Lower values of Nu than those predicted by equation (1) would, therefore, be expected.

To get an estimate of Nu in this case, Colburn's relation[5] for turbulent flow is here applied to Ribary's test data for friction torque on a rotating disc[4]. The following relations are obtained:—

$$j = f/2 \quad . \quad . \quad . \quad . \quad (2)$$

where f = friction coefficient

$j = St \times Pr^{2/3}$

$St = \dfrac{h}{c_p V \rho}$ (Stanton number)

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$Pr = \dfrac{c_p \mu}{k}$ (Prandtl number)

c_p specific heat at constant pressure

V $\omega D/2$

μ dynamic viscosity

ρ density

Equation (2) applies to local values of both coefficients j and f. From Ribary's data

$$f \text{ mean} = 0{\cdot}0409\, Re^{-0{\cdot}20} \quad . \quad . \quad (3)$$

where $f \text{ mean} = \dfrac{\text{Torque}}{2\displaystyle\int_0^R \frac{\rho}{g} \pi\omega^2 R^4 dR}$.

It is easily found by integration that

$$f \text{ local} = 1/5\,(5+2b)\, f \text{ mean} \quad . \quad . \quad (4)$$

where b is the index of Re in the power relation for f. Combining equations (2), (3) and (4) and assuming $Pr = 0{\cdot}74$ gives

$$Nu \text{ local} = 0{\cdot}01702\, Re^{0{\cdot}80} \quad . \quad . \quad (5)$$

It can also be found that if the disc to air temperature difference is independent of the radius

$$Nu \text{ mean} = 2/(1+2c)\, Nu \text{ local} \quad . \quad . \quad (6)$$

where c is the index of Re in the power relation for Nu. Hence

$$Nu \text{ mean} = \frac{2}{2{\cdot}6}\, Nu \text{ local} = 0{\cdot}0131\, Re^{0{\cdot}80} \quad . \quad (7)$$

For $Pr = 0{\cdot}72$ a value for Nu mean of $0{\cdot}013\, Re^{0{\cdot}80}$ is obtained; this is only about 75 per cent of Nu as predicted by equation (1).

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The Measurement and Analysis of Gust Structure

by

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THE CLASSICAL VIEW OF GUST STRUCTURE

THE gustiness of the atmosphere is studied, among other reasons, because of its importance in producing loads on aeroplane structures much larger than the loads occurring in calm air.

Atmospheric turbulence is studied by observing the behaviour of aeroplanes passing through it, by observing the motion of balloons or other articles carried along by the wind itself, or by examining the fluctuations in velocity or direction occurring at a point fixed relative to the earth. The first of these methods is the most flexible and is the most convenient for aeronautical investigators. In this case the aeroplane becomes the measuring instrument and the reactions of this instrument are recorded by a second instrument, either a strain recorder which charts the fluctuations of strain in some part of the structure or an accelerometer which charts the acceleration of some point near the centre of gravity in a direction normal to the direction of motion along the flight path (or normal to some axis in the aeroplane roughly parallel to the flight path). The appearance of such records taken on a time base is well known: the trace fluctuates irregularly about a mean which is the straight-and-level flight value; small deviations from the mean are much more frequent than large ones.

Where considerations of ultimate design strength of aircraft are paramount, interest becomes centred on the larger deviations from the mean, and consequently on the rarer occurrences. To expedite the collection and analysis of data, some form of statistical instrumentation which classifies the occurrences and extracts the rare large ones is valuable: such instruments are the *V-g* recorder, the counting accelerometer and the counting strain meter. These instruments all record the maximum or peak value of the response of the aircraft to the impressed gust disturbance, as does the "simple" analysis of a continuous time record.

If all aircraft responded in the same manner to the atmospheric disturbances, or if the research were confined to aircraft of one type (all having the same response behaviour) it could be concluded that the most severe acceleration or strain increment was produced by the most severe gust. (For the moment attention will be confined to aircraft having the same response, but it will be necessary to return later to consider the situation of comparing data from aircraft having different response behaviours.) It might be thought (in fact, it has been thought) that if the recording were continued for some time, say for some thousands of hours, an upper limit would be found which was not exceeded with the continuance of recording. On the other hand, considerations of the random nature of the gustiness, and of the analogy with the Gaussian distribution, suggest that such a limit does not exist—and this is found experimentally to be the case.

As a consequence it becomes impossible to establish a "most severe gust" which will never be exceeded—and the philosophy has been adopted of establishing the "very rare gust" which will only be exceeded once, on the average, in a period of perhaps 10^7 or 10^8 flying hours, *i.e.* expected to be exceeded with a probability of 2×10^{-3} to 2×10^{-4} in the flying life of one aeroplane.

A closer examination of continuous records reveals that, particularly for the more severe gusts, the maximum value of acceleration or of vertical velocity does not appear instantaneously, but takes some time to build up. These changes in velocity are pictured as resulting from a two-or-three-dimensional velocity field, such as would result from there being a number of vortices throughout the space. If these vortices remain fixed in position with time, so does the velocity field, and the changes measured by the aircraft result from its motion in the time-stationary pattern. Thus the build-up time to any maximum value of velocity (*i.e.* to any gust) becomes a function of aircraft speed, but the build-up distance is invariant.

Thus has arisen the concept of a "gust gradient distance" to be associated with each gust, and in particular, the design gust. The response of the aircraft is known theoretically to be dependent on gradient distance, and it is the response rather than the original gust disturbance which is normally measured. No difficulty is encountered in comparing the relative severities of gusts on two aircraft of the same type by comparing the relative responses (*i.e.* the measured normal accelerations) and it would be quite permissible and logical to adopt the maximum value of aircraft response (acceleration) instead of the vertical gust velocity as a design criterion.

When the measured conditions on one aircraft type must be used as a guide for design of others having different response characteristics, it is essential that the differences be allowed for adequately.

GUST STRUCTURE AS A CONTINUOUS FUNCTION

Consideration of the fluctuations of wind speed with time or of aircraft acceleration with time or distance has shown that these quantities are, more or less, random variables.

Any *recurring* function can be represented (through a Fourier analysis) by a series of sinusoidal functions, defined in amplitude, frequency and phase. A plot of amplitude against frequency of this function would appear as a line spectrum, the height of each line representing the amplitude of the component with that frequency. If the phases of each other component relative to one chosen component (usually the fundamental) were known the wave shape would be completely determined—thus the spectra give a means of characterising the wave shape without actually drawing it. If necessary the original curve can be uniquely reconstructed, and other relevant characteristics determined. Such characteristics could be, for example, the probability

(*a*) that at an instant chosen at random the amplitude lay between certain limits;

(*b*) that a peak, chosen at random, lay between given limits;

(*c*) that the time of rise between successive turning points (minimum and maximum) lay within given limits.

If this recurring function were applied as a disturbance to a dynamical system, the response could be determined by calculation—the more complicated the dynamic system,

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the more complex the evaluation of response—but it is considered that any practical problem could quickly be solved using existing techniques with digital or analogue computers.

As the wave form becomes more complex more frequency components (harmonics) and phases are required to specify completely the recurring function. For example, if we make one Fourier analysis of the fundamental or "repeat length" of a recurring curve and another analysis of a length equal to twice the repeat length there will be the same number of frequency components in each analysis. If in the latter case the second half of the curve is not an exact replica of the first, then more frequency components will appear with accompanying changes in the values of amplitude, *i.e.* the curve has become more complex. In the limit, if the boundaries within which the curve or function is analysed are widened to infinity the curve becomes non-repetitive and an infinite number of frequency components is required to define the curve, and the spectrum of amplitude against frequency becomes a continuous curve, instead of a line spectrum. The relative phase relation between components plotted against frequency is a continuous curve called the phase spectrum.

The plot of energy in any frequency component against frequency as independent variable is called a power spectrum (using the nomenclature of electrical engineering): this and the phase spectrum can completely characterise an irregular, non-recurring function. Two random functions having the same power spectrum and phase relation can be regarded as the same random function, even though it is impossible to superimpose any finite length of the first curve directly upon a similar length of the second. On the other hand, two random functions having the same power spectrum may have different wave shapes if the phase relationships are different. For example, electrical random noise is a random function of time: its amplitude distribution is of the simple "Gaussian" or "normal" form, and its power spectrum is of constant magnitude from zero frequency up to infinite frequency. The phase relation between the various components is random. The same power spectrum characterises a square wave with random time intervals between the "flip" and "flop" conditions, only in this case there is a particular phase relation between the various frequency components.

DYNAMIC RESPONSE TO A GUST DISTURBANCE

If one considers the effect of some random function as a disturbance acting upon a dynamical system, the power spectrum of the former differs from that of the response as a result of the modifying effects of the responding system—that is to say, by its selectivity, or ability to resonate more strongly with one, or several, frequencies than with others. In a recording of the response of a highly resonant system to an irregular disturbance it will be possible to pick out oscillations at the resonant frequency, building up and dying away, when it happened by chance that peaks of the disturbance arrived at more or less the resonant frequency of the system. The power spectrum will exhibit a peak at each resonant frequency (such as does not occur in the spectrum of the disturbance function) and with very low damping will tend towards a line spectrum. The effect of the responding system may be likened either to a resonator which is more sensitive to certain frequencies, or alternatively to an electrical filter, which attenuates signals outside the relevant frequency bands, and permits those in the acceptance bands to come through less attenuated. Unless the responder has uniform response at all frequencies the power spectrum of the response will be a modified form of that of the disturbance. Power spectrum analysis is thus a powerful tool for determination of natural frequencies of response of the dynamic system.

From the aeronautical aspect, if the power spectrum of a disturbance were known, as well as the dynamic characteristics of a responding system (its transfer function) the response of the system could be considered known—not as regards the absolute magnitude of response at any instant, but in the statistical sense, as regards the probability that the response will lie within given limits. Thus the earlier conception of a design gust velocity with specified gradient distance would be superseded by the concept of a design maximum value of response occurring with a specified low value of probability. Different aircraft will have differing response behaviour (transfer functions), resulting in different values of design response for the same low probability of occurrence.

CHARACTERISTICS OF THE ATMOSPHERE

If the disturbance is what is called a non-stationary random function of time, its characteristics, *i.e.* either the shape or the amplitude or both of the power spectrum are not constant as functions of time. This is the case with air turbulence which varies from immeasurable to severe, according to the topography, with the presence of cloud, with storms and with cold fronts. Ideally the power spectrum should be determined for each part of the function or curve which is "stationary random" and when the function has changed significantly, a new power spectrum should be established. In practice there is a limiting lowest frequency (longest wavelength) into which a length of curve can be analysed—of the order of 1/10 of the length of the record.

In general, turbulence generated by different means or in differing states of growth or decay will be expected to have differing power spectra.

If the whole of the gust velocity field were to remain unaltered in shape and an aircraft were imagined to travel at constant velocity along a line through it, the rate of change of gust velocity would be directly proportional to aircraft speed. Thus there would be a direct and determinable relation between the wave forms and power spectra seen by the measuring instrument (the aeroplane), if two experiments were made at different speeds. Similarly, if the pattern were blown by the wind past a stationary observer on a tower the direct relationship would be maintained. However, it is not true that the velocity field remains unaltered, so that, quite apart from any difference in responsiveness of the aeroplane and the instrument on the tower, the shape of the wave forms as seen by the two observers would differ, and presumably the power spectra (and perhaps the phase relationships).

It is precisely at this point that present ideas fail to convey clearly what is the relationship between the gustiness seen by observers in relative motion. It is not clear, also, whether it is adequate to assume a random phase relation and whether the wave form can be characterised by the power spectrum only, and no experimental data are available on this aspect. If these points could be settled, a way would be open to characterise the turbulence independent of the characteristics of and of the motion of the measuring instrument, and computational tools are already available to establish the response of a system in arbitrary motion in or through this turbulence.

The response of the aircraft would then, in theory, be fully known (in the statistical sense) and questions of frequency and magnitude of applied loads, stability, and so on, would be settled in one step.

*A Note on the Wave Drag of "Exposed" Rectangular Wings**

by

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THIS NOTE GIVES a simple relationship between the zero-lift wave drag of the wing of a rectangular wing and body combination and the wave drag of the portion of the gross wing blanketed by the body, both evaluated as if isolated (*i.e.* ignoring the interference of other parts of the combination). The result is valid only when the tip Mach cones of the wing lie downstream of the blanketed wing. Detailed results are given for the case of wings with double-wedge section, the maximum thickness being at mid-chord.

INTRODUCTION

A useful concept in problems of wing-body interference is that of an exposed wing, which is defined to be that portion of the gross wing actually outside the body of the configuration. The estimation of the zero-lift wave drag of wing-body combinations using the area rule or transfer rule (*see*, for example, Ref. 1), is much simplified when the wave drag of the isolated exposed wing is known. For this reason it is desirable that the calculations involved in estimating exposed wing wave drags are simplified as much as possible. In the special case of a non-lifting rectangular wing of constant section it has been found possible to derive a relationship between the wave drag of the isolated exposed wing and the wave drag of the isolated blanketed wing, which is that portion of the gross wing blanketed by the body. This relationship enables analytical expressions for the exposed wing wave drag to be found when the wing section is double-wedge or parabolic-arc. These results are especially useful since, when the body of a configuration is a cylinder, they give an estimate[2] of the total wave drag if the interference velocity potential between the exposed wing and the body is neglected.

DERIVATION OF RESULT

An isolated rectangular wing with the tip Mach cones downstream of the blanketed wing is shown in Fig. 1. It is desired to determine the effect on the wave drag of the mutual interference between the two exposed wing panels W_l and W_r. The wing carries no local lifting forces and the section is constant.

Consider the gross wing W_o and divide it into two sections W_l and $(W_r+\Delta W)$. Using Young's theorem[3], for example, it follows that the pressure field of W_l has no net effect on the wave drag of $(W_r+\Delta W)$. Hence, due to the presence of W_l, the wave drag of W_r is decreased by an amount equal to that portion of the wave drag of ΔW which is due to the pressure field of W_l. A similar result holds for the effect of W_r on the wave drag of W_l.

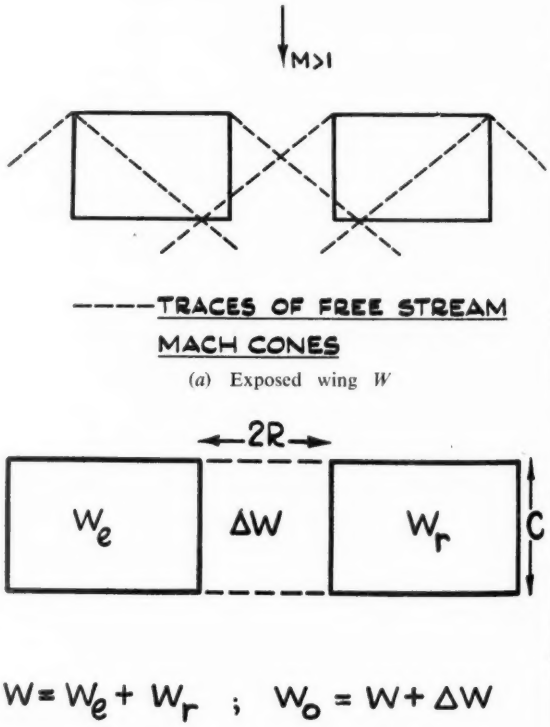
But the ΔW portion of the gross wing flow field, which is two-dimensional over ΔW, can be built up by superposing the pressure fields of the exposed wing panels W_l, W_r and the blanketed wing ΔW. Therefore the mutual interference between the exposed wing panels W_l, W_r results in a wave drag decrease equal to the magnitude of the difference between the "exact" value of the isolated blanketed wing wave drag and the value of the blanketed wing wave drag calculated by a two-dimensional strip method. Since the tips of the exposed wing have no net effect on the wave drag, the isolated exposed wing wave drag can be written as*

$$D_{\mathrm{W}} = \{D_{\mathrm{W}}\}_{(2)} + D_{\Delta \mathrm{W}} - \{D_{\Delta \mathrm{W}}\}_{(2)} \quad . \quad (1)$$

where $\{D_{\mathrm{W}}\}_{(2)}$ denotes the exposed wing wave drag, calculated by a two-dimensional strip method

$D_{\Delta \mathrm{W}}$ denotes the isolated blanketed wing wave drag

and $\{D_{\Delta \mathrm{W}}\}_{(2)}$ denotes the blanketed wing wave drag, calculated by a two-dimensional strip method.



(*a*) Exposed wing W

(*b*) Blanketed wing ΔW and gross wing W_o

FIGURE 1.

*The work described in this note was carried out while the author was at the Royal Aircraft Establishment, and appeared as RAE Tech. Note Aero 2494.

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*Since this work was completed the author has learned that the same result has been derived by R. C. Lock[4].

Equation (1) can be written in the alternative form

$$\frac{BC_{D_W}}{\tau^2} = \frac{B(C_D)_{(2)}}{\tau^2} + \frac{2}{AB} \cdot \frac{BR}{c}\left(\frac{BC_{D_{\Delta W}}}{\tau^2} - \frac{B(C_D)_{(2)}}{\tau^2}\right) \quad (2)$$

where the drag coefficients D/qS are based on the area of the wing portion being considered.

$q = \frac{1}{2}\rho_0 V_0^2$, kinetic pressure

ρ_0, V_0 free stream density and velocity respectively

$B = \sqrt{(M^2-1)}$, M being the free stream Mach number

τ thickness-chord ratio of the wing section

R radius of that circular cylinder just enclosing the blanketed wing

c wing chord

$A = (b-2R)/c$, the exposed aspect ratio, b being the gross wing span.

The coefficient $(C_D)_{(2)}$ denotes the two-dimensional wave drag coefficient for the wing section. Since the wing tip Mach cones do not cross the blanketed wing ΔW, equation (2) is valid for $AB \geqslant 2$.

EXAMPLE

The special case treated here is that of an exposed rectangular wing with a double-wedge section whose profile is symmetrical about the mid-chord. In this case the two-dimensional wave drag coefficient of the wing section is given by

$$\frac{B(C_D)_{(2)}}{\tau^2} = 4$$

and following Nielsen[5],

$$\frac{BC_{D_{\Delta W}}}{\tau^2} \begin{cases} = 4, & \frac{BR}{c} \geqslant \frac{1}{2} \\ = 4 - \frac{4}{\pi}\left[\frac{\sqrt{[1-4(BR/c)^2]}}{2BR/c} + 2\frac{BR}{c}\cosh^{-1}\left(\frac{1}{2BR/c}\right) - 2\cos^{-1}2(BR/c)\right], & \frac{1}{4} \leqslant \frac{BR}{c} \leqslant \frac{1}{2} \\ = 4 - \frac{4}{\pi}\left[\frac{\sqrt{[1-4(BR/c)^2]}}{2BR/c} + 2\frac{BR}{c}\cosh^{-1}\left(\frac{1}{2BR/c}\right) - 2\cos^{-1}2(BR/c)\right] \\ \quad - \frac{4}{\pi}\left[-\frac{\sqrt{[1-16(BR/c)^2]}}{2BR/c} - 8\frac{BR}{c}\cosh^{-1}\left(\frac{1}{4BR/c}\right) + 4\cos^{-1}4(BR/c)\right], & 0 \leqslant \frac{BR}{c} \leqslant \frac{1}{4}. \end{cases} \quad (3)$$

It follows that, using equation (2)

$$\frac{BC_{D_W}}{\tau^2} = 4\left(1 - \frac{2}{AB}\cdot\frac{BR}{c}\right) + \frac{2}{AB}\cdot\frac{BR}{c}\cdot\frac{BC_{D_{\Delta W}}}{\tau^2}, \quad AB \geqslant 2. \quad (4)$$

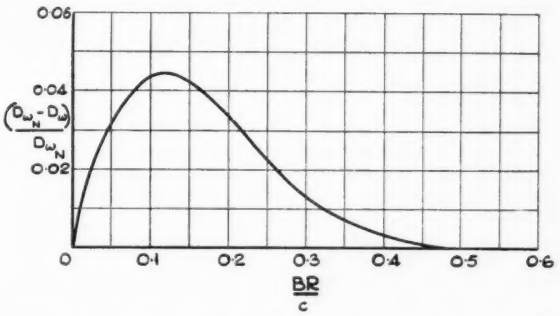

FIGURE 2. Wave drag, D_W, of exposed rectangular wing with double-wedge section, the maximum thickness being at mid-chord $AB=2$. D_{W_N} = wave drag of net wing. $C_{D_{WN}} = C_{D(2)} = 4\tau^2/B$.

Equation (4) is shown in Fig. 2 for $AB=2$, Nielsen's plot[5] of equation (3) being used. It will be seen that the wave drag of the exposed wing is within about 4 per cent of the wave drag of the net wing, which is defined as the wing formed by placing together the exposed wing panels, *i.e.* expressed as a coefficient the wave drag of the exposed wing does not differ greatly from the two-dimensional value.

A wing with parabolic-arc biconvex section could be treated also by using Harmon's result[6] for the wave drag of low aspect ratio rectangular wings with parabolic-arc biconvex section. Plotted in the form of Fig. 2 the results, given by Lock[4], are very similar to those for the double-wedge section.

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Rotary Stability Derivatives from Distorted Models

by

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(Department of Aeronautics, University of Sydney)

FOSTER AND HAYNES recently suggested[1] the possibility of measuring the rotary stability derivatives of an aeroplane by testing a suitably distorted model in a wind tunnel. This possibility has been examined for an isolated wing by the authors and has been found to be in error for the derivatives due to rolling and yawing.

In what follows it will be assumed that thin aerofoil theory and Prandtl's lifting line theory may be applied.

Received 27th January 1958.

PITCHING

The use of a model with distorted camber is justified to the first order for thin aerofoils by the analysis made by Glauert[2].

ROLLING

If the distorted model is obtained by twisting the given wing through an angle (py/V) about a spanwise axis, as suggested by Foster and Haynes, then the incidence and therefore the lift and downwash distributions will be identical on the distorted and on the rolling wings. However, the resultant velocity in the case of the rolling wing is rotated through (py/V) relative to the wing chord, whereas no such rotation occurs with the distorted wing. Thus although the rolling moment will be correct to the first order, this will not be so for the yawing moment.

YAWING

In the yawing case, the distorted wing has its chord increased locally to $c(1 - yr/V)$ and its incidence increased to $\alpha(1 - yr/V)^{-1}$, where c and α are the local chord and incidence respectively. Thus by strip theory the suggested distortion leads to zero change in both the yawing and rolling moments. Further examination of a particular plan form using Prandtl's theory yielded a rolling moment which was in fact in the opposite sense to that which would be expected.

It is not, in general, possible to obtain distorted models which will give correct results except in the pitching case. This follows from the fact that to obtain the correct rolling and yawing moments, the lift and downwash distributions must be specified independently, and this is inconsistent with Prandtl's theory.

REFERENCES

1. FOSTER, D. J. and HAYNES, G. W. (1956). Rotary Stability Derivatives from Distorted Models. *Journal of the Royal Aeronautical Society*, September 1956.
2. GLAUERT, H. (1928). The Lift and Pitching Moment of an Aerofoil due to Uniform Angular Velocity of Pitching. R. and M. 1216, 1928.

Rear-Engined Air Liners

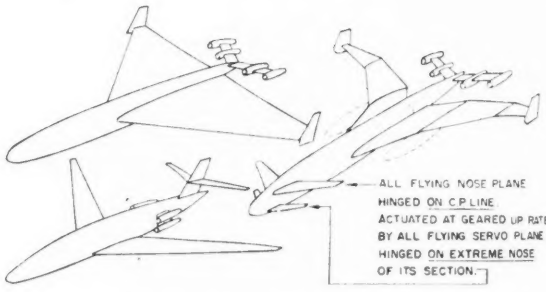
by

A. W. J. SMITH, A.R.Ae.S.

I SHOULD like to raise a point on the projected rear-engined jet air liners now under active consideration by several major British firms and of which "artists' impressions" have recently been published, the latest being the V.C.10.

The rear-engine layout has so many advantages that its use seems entirely logical, but I am curious to know whether or not such a design has been investigated with a noseplane layout in preference to the conventional tailplane. I have been interested in this possible configuration for some years and put the idea forward in a short Branch lecture at Derby when it appeared that quite a few of those then present agreed in broad principle.

It does seem that a noseplane layout on a large air liner with rear engines would enable the use of a longer lever arm and smaller volume subsidiary surfaces; a much cleaner, more compact tail and with probably a considerable reduction in overall height; a reduction in complication and weight of control mass and less vital structure in the area of the engines should, by any misfortune, a major engine failure occur. Further, if the noseplane consisted of, in fact, a biplane unit, with an all-moving servo plane hinged at the leading edge providing the moving force for the other all-moving plane hinged at the approximate centre of pressure and with suitable control and trim interlinkings, the aircraft might be made very stable over a wide speed range and without the need for complicated power operated controls.


ALL FLYING NOSE PLANE
HINGED ON C.P. LINE
ACTUATED AT GEARED UP RATE
BY ALL FLYING SERVO PLANE
HINGED ON EXTREME NOSE
OF ITS SECTION.

Some of the configurations suggested in the paper given to the Derby Branch in January 1954.

I would be very interested to know whether or not any of the firms have in fact considered a noseplane layout and if so, the reasons for its rejection.

Received 16th January 1958.

Graduates' and Students' Section

The Electronic Digital Computer

A most interesting lecture entitled "The Electronic Digital Computer" was delivered to the Section on Thursday 6th March by Mr. W. F. M. Payne of Ferranti Ltd.

The first serious attempt to design and build such a machine was that of Charles Babbage, a mid-nineteenth century scientist who, after a great deal of work, eventually constructed the world's first digital computer from a miscellany of wooden cogs and metal strips. However, little progress was made in the next 100 years and it was not until the end of the Second World War that the computer industry as it is known today was born. Since 1945, rapid progress has been made in computer design and techniques and at the present time about 1,500 digital computers are being applied in numerous roles within the non-communist countries.

It is important to distinguish the different underlying principles between an ordinary calculating machine and a computer. Whereas the calculating machine can only perform one operation at a time without human intervention, a computer can be given a complete set of explicit instructions which will be obeyed in a specified order without any human action whatsoever. It is this property, combined with the electronic speed at which the computations are made, which makes the digital computer such a powerful aid to industry.

There are four main sections to any computer system:—

(*i*) *Input/Output Units.*—There must obviously be means of passing data, instructions and results into and out of the system. Either paper tape or card is used as the medium for these operations and the function of the input unit is to read this information and translate it into the language of the machine. On output exactly the reverse process occurs.

(*ii*) *Storage Units.*—To provide means of storing the instructions to the machine (the Programme) and intermediate results required for later stages in the computations. This facility is provided in one or more of the following ways:—

(*a*) Magnetic tape.
(*b*) Magnetic drum.
(*c*) A wired mesh of very small metallic cores.
(*d*) Delay lines.

The first three rely on normal principles of magnetism. The fourth is essentially a closed circuit round which the data is circulating in the form of electrical pulses.

(*iii*) *The Arithmetical Unit.*—That part of the system in which the actual computations are executed. It can perform a number of operations, including the basic mathematical ones of addition, subtraction, multiplication and division.

(*iv*) *The Control Unit.*—That part of the system which interprets the instructions given to the machine and generally controls the whole operation of the machine.

The lecturer concluded with a brief summary of the uses of digital computers. A substantial number, many of them in the aircraft industry, are being applied to very complex technical computations, while others are being utilised for more commercial tasks such as payrolls, stock control and production planning. Without doubt their numbers and scope will increase enormously in the future.

VISITS

B.O.A.C.

As mentioned briefly last month, we are due to have a visit to B.O.A.C. at London Airport on the afternoon of Saturday 31st May 1958. Arrangements are still not complete, but those interested should write to the Hon. Visits Secretary, Mr. N. K. Benson, 14 Wakering Road, Barking, Essex.

Lotus Engineering

On the evening of Friday 28th February we had a second visit to the Lotus works at Hornsey where the exciting racing cars are built. The organisation, though still very small, appears to have doubled in size since our last visit 13 months earlier.

We saw the tiny shop in which their "routine" production of Mark XI sports cars takes place at four per week. They produced the incredible number of seventeen in one week when there was threat of the imposition of Purchase Tax! We saw here the prototype Mark VII which many magazines have tested. The Mark VII is the "poor man's model" with Ford engine, whereas they use Coventry Climax engines in their other cars, now becoming somewhat distant relatives of the original fire pump unit.

In the experimental shop we saw the prototype of the Mark XV sports cars for Le Mans and Formula One Grand Prix cars which have many features in common, including the remarkably compact and ingenious Lotus 5-speed gearbox, twin o.h.c. Climax engine nearly lying on its side and entirely new chassis which can only be described as flimsy. The racing car will be a mere 32 in. high to the top of the driver's head, and the cars for Le Mans will have bonnets 4 in. lower than on the Mark XI. Drivers would appear to be installed with a shoe horn.

The engineering of these cars is obviously of very high quality with simplicity and ingenuity abounding everywhere. The result is cars of almost absurd lightness and performance rather better than fantastic.—N.K.B.

LECTURES—Spring Session

The following lectures (to be held in the Library, 4 Hamilton Place, at 7.30 p.m.) will complete the Lecture Programme for the Spring Session:—

18th April—The Role of the Independent Airlines in British Air Transport Development, by T. W. Morton, Chairman, British Independent Air Transport Association.

5th May—Future Trends in Naval Air Operations, by Captain O. M. Bailey, O.B.E., R.N.

THE LIBRARY

Reviews

HISTORY OF GERMAN GUIDED MISSILES DEVELOPMENT. *Edited by T. Benecke and A. W. Quick. AGARDograph No. 20. Verlag E. Appelhans and Co., Brunswick, Germany 1957. 420 pp. Illustrated. 55s.*

This book records the proceedings of the first Guided Missiles Seminar held under the auspices of AGARD at Munich in April 1956. All aspects of German work on guided missiles up to 1945 are discussed in 26 papers, whose authors were closely concerned with the developments they describe. Four German missiles became operational: two of these were surface-to-surface, the V1 and V2, which to Londoners need no introduction; the other two were air-to-surface, the "Fritz X" and the Hs 293, both guided bombs with command control. A great deal of research effort was expended too, as the papers in this volume show, on missiles which never came into service. Those which were nearly ready included the surface-to-air missile Schmetterling, and the wire-guided X-4 (air-to-air) and X-7 (anti-tank), from which the French anti-tank missiles have been developed. All these were subsonic, but the supersonic surface-to-air Wasserfall was also well advanced.

The papers in the book may be divided into subjects as follows. There are two papers on aerodynamics, three on control, eight on guidance, one on fuses, nine on propulsion (five on rockets, two on ram-jets, and two on pulse-jets), and three giving a general review of missiles being developed. This division of emphasis between the various subjects seems in general to be fair, though one would have expected rather more on aerodynamics. The two papers on this subject which are given—on the aerodynamic development of the V2 and on spoiler controls—are most interesting, but it is a pity that there is no account of the research on supersonic air intakes, apart from a short section in one of the papers on ram-jets.

A high standard is maintained by almost all the authors and one would scarcely guess that some of them were writing entirely from memory. The translation, too, is most satisfactory, and the book is handsomely produced, with very few misprints. Some British readers may find a jarring note from time to time when a paper seems too bombastic or the discussions unduly contentious; but these occasions are few and far between. It should perhaps be remarked that the title of the book is misleading: a series of technical papers does not constitute a history. A better title would be "German guided missile development." Also it may still be worth protesting about that monstrous "word" AGARDograph.—D. G. KING-HELE.

STRENGTH OF MATERIALS. *F. R. Shanley. McGraw-Hill, London, 1957. 783 pp. Illustrated. 64s.*

Although this book is written with the needs of the general structures student in view, and therefore contains some reference to such things as reinforced concrete and bridge structures, the emphasis is on the application of the basic principles of materials and structures. As anyone would expect, who is familiar with the work of Professor Shanley, the book has a bias towards aeronautical applications and contains a great deal of information which should prove valuable to the aeronautical engineering student and engineer.

The first chapters are concerned with elementary principles and continues throughout the subsequent chapters to outline in a most rational manner the effect of loads on structural elements and the effect of complex loading and buckling problems.

It is inevitable that in any book of this type that there is some repetition of the material which has been written about many times in the last few years, but the presentation of this work is of the highest standard, and continual reference to the historical derivations makes this book particularly valuable from the student's point of view.

Criticisms are few, but one might have expected the author to have put a far greater emphasis on thermal effects, which play a very big part in the analysis of all forms of engineering structures, and are often difficult and confusing for the student to understand.

The book is divided into three main sections. The first section is concerned mainly with forces and deflections, stress and strain, and the energy theorems, whilst section two is concerned with the analysis of the structural elements.

Section three is particularly useful, since it contains a wealth of valuable information for the young stressman, and includes some of the latest concepts of buckling, stress concentration, fatigue and the strength of joints and fittings.

Experience in teaching has shown that the young engineer can generally absorb the engineering principles given in a lecture, but it is not until he has tried to apply these principles to practical engineering problems that the real difficulties become apparent.

The author quite obviously had this in mind when he decided to include so many useful worked and unworked problems.

The illustrations and general production are of a high standard and the book can be recommended as a concise and well written work on Strength of Materials, eminently worthy of one of the foremost workers in the field of structural analysis.—D. S. HOUGHTON.

SOVIET AIR POWER. *Richard E. Stockwell. Pageant Press Inc., New York, 1956. 238 pp. Illustrated. $7.50.*

This is a book with a message, which runs as follows: The rate of progress in Soviet aviation during the last ten years is demonstrably tremendous, and the Russians have now caught up with the West. The only barrier against a return to the Dark Ages being the continued technical superiority of the U.S. Air Force an apathetic public must be aroused to insist that steps be taken to ensure that this superiority is not lost.

In order to establish his contention, the author, former editor of "Aviation Age," assembles an impressive number of facts about Soviet air power. Thus, the book is partly factual, partly crusading in character.

Ten chapters record the history and present status of the Russian aircraft industry. There is an account of early Russian aviation up to 1945, of the intensive efforts made after World War II to catch up with the West and of the use of German engineers and equipment. The development of contemporary Russian aircraft, engines and missiles is described and there are chapters on the operation

of civil aircraft and on training and education for the air forces and the technical services. The present organisation of Soviet aircraft production and operation is discussed. A separately bound supplement comprises tables of aircraft and engine characteristics, and there are a number of photographs, drawings and three-view silhouettes in the main volume.

The style of writing is inclined to be rambling, repetitive and even gossipy. Considered purely as a technical appraisal of contemporary Soviet aircraft, the book lacks true perspective. For example, we are left in no doubt about the superior altitude performance of the MiG 15 vis-a-vis the F.86, yet the fact that its transonic flying qualities are akin to those of a brick is not mentioned. Again the smaller weight of equipment on Soviet fighters compared with some of their Western counterparts (including, presumably, the apparent absence of airborne radar on most of them) is presented as an unqualified virtue. Engines are discussed as if the sole yardstick of merit were the static thrust, irrespective of size and weight.

No comments are made on particular external design features of Soviet aircraft, *e.g.* the lavish use of boundary layer fences, the apparent preference for nose intakes on jet fighters, the use of tail armament on relatively small fast aircraft.

There are a number of obvious, careless errors in the book. Two of the silhouettes do not correspond with the pictures by them, and there is some confusion between the light bombers "Beagle" and "Bosum" (cf. p. 97 and the supplement).

To sum up, then, here is a book which anyone interested in Soviet aviation—and that means most of us—will want to read for the information it contains, in spite of the fact that the information is served up in a manner reminiscent of a popular newspaper. As for the message, the buoyant, up and coming Russian aircraft industry certainly presents the West with a challenge, commercial as well as military. In Russia it is apparently both very respectable and very remunerative to be a successful aeronautical engineer, and new recruits to the industry are being trained at a prodigious rate.—J. R. COLLINGBOURNE.

MAGNETOHYDRODYNAMICS. *Edited by R. K. M. Landshoff. Stanford University Press, California, 1957. 115 pp. Illustrated. 32s.*

Magnetohydrodynamics is the study of the flow of electrically conducting fluids in the presence of magnetic fields, a subject which has long been of interest to astrophysicists; more recently, of course, it has found practical engineering application in the control of the very hot gases which will be required if power is to be obtained from thermo-nuclear fusion. It is chiefly this latter interest which guides the large amount of research work at present going on into the properties of a hot ionised plasma in the presence of a magnetic field.

In December 1956, the Lockheed Missile Systems Division sponsored a symposium on magnetohydrodynamics, and this book, we are told, grew out of the talks and discussions held there.

Of the eleven contributions, the first five deal with theoretical topics. The first is an introduction to the subject, by means of a classification into domains, using mainly dimensional arguments; the second starts from Maxwell's equations and the equations of motion, and deduces some important dimensionless parameters. A simple mechanism for the build-up of large magnetic fields inside stars is suggested in the next paper, and this is followed by a detailed analysis of the penetration of a shock wave into a magnetic field. The last theoretical paper outlines an analysis of the dynamics of a pinched gas. Next, to open the section on laboratory experiments, there is another, simpler, essay on dimensionless parameters; this is followed by three papers on magnetically driven shock waves. The first two papers run just about parallel, and present similar data obtained from similar apparatus, while the third is far too brief to be of much help. Finally, the book ends with a description of an experiment to study a type of flow instability, and an interesting proposal for a magnetohydrodynamic wave guide. Of the eleven contributors to the Symposium, the following have been chosen for prominent display on the cover of the book: Jan M. Burgers, Walter M. Elsasser, Fred Hoyle, Arthur Kantrowitz and Marshall Rosenbluth.

The quality of the subject matter varies widely from one paper to another, and some of the articles are too short to be regarded as more than brief summaries of research reports; also, the standard of previous knowledge which the authors demand of their readers is very variable. However, the book must be considered as a whole, as it is not possible to review each paper separately. Considered simply as the Report of a Symposium on magnetohydrodynamics, it will undoubtedly be most helpful; some new and original work is summarised, and references to the technical literature are given for those who want more details. A wide range of interesting topics are covered by experts in several fields.

However, the editor tells us that it aims to be more than a direct report of the proceedings of the Symposium, as an attempt has been made to present the material in an integrated manner, by avoiding duplications and filling in gaps. The present reviewer feels that this attempt has not been entirely successful: the book still consists of a number of independent essays, and numerous duplications do occur. A better over-all effect might have been achieved if some of the shorter articles had been filled out with more background information.

Workers in the field of magnetohydrodynamics will find this book useful as a summary of the contributions made at the Lockheed Symposium, while for those less familiar with the subject, it will provide a good introduction to some aspects of a new and rapidly growing field.—K. N. C. BRAY.

THE MAKING OF A MOON. *Arthur C. Clarke. Muller. 182 pp. Photographs. Diagrams. 21s.*

SATELLITES AND SPACEFLIGHT. *Eric Burgess. Chapman & Hall. 159 pp. Photographs. Diagrams. 21s.*

OPERATION VANGUARD. *Werner Buedeler. Burke. 128 pp. Photographs. Diagrams. 16s.*

Those of us who have believed in the imminent practicability of satellites and space-flight for some years past have often stressed the fact that such achievements would have much more than a merely technical significance, turning men's minds from mundane earthly affairs to thoughts of their place in the cosmos and perhaps making them realise that a great many of those earthly affairs were more deserving of the jibe of being adolescent than is the subject of astronautics, which has sometimes been its target. Also, from frequent invitations to talk and write about it, we have been well aware of an extremely widespread and very sympathetic interest in our particular enthusiasm, among all sections of the community.

Even so, we were hardly prepared for the fact that the launching of the first artificial satellites of the Earth would precipitate something like an international crisis, and what can fairly be described as near-panic in certain American

quarters, at least. These factors, together with the actual event of the launchings themselves and the considerations already mentioned, should ensure a ready market for the three books reviewed here.

They are very much three of a kind, and from any one of them the reader would gain an excellent semi-technical understanding of the principles of rocket propulsion and satellite flight, the scientific observations which it is planned to make from the first instrumented satellites, the problems of tracking their orbits, and the more advanced phases of space-flight into which they may confidently be expected to lead.

Of course, all three books were written in the expectation that the first satellite rocket would be the American "Vanguard." This is particularly evident in the best of the three, in the writing of which Mr. Clarke acknowledges the special help of the Martin Company and other contractors on this project. His face must surely be red whenever he thinks of the statement on p. 36 regarding the original decision of the IGY Committee recommending the establishment of rocket satellites: "only the United States . . . took action on the resolution or indeed was in a position to do anything concrete about it."

They are also plenty of red faces today among those responsible for American rocket projects, as well as those who write about them; a comment recently made to the present reviewer was: "Over here, heads are shrinking so fast you'd think the Javanese had been at work." Perhaps one of the most useful non-technical consequences of the sputniks will prove to be their deflation of our Western scientific conceit—although how any student of post-war developments could be so surprised at the Soviet achievements as most people seem to have been is in itself a source of surprise to me, at least. There is particularly little excuse for surprise for anyone who attended the International Astronautical Congresses of 1955 and 1956.

However, let us not under-estimate our American friends, and above all let us not forget that they *are* our friends. They will recover from this shock, and—once they have made their direction of the U.S. effort on rocketry even half as competent as its technical content—they will go on to success with the "Vanguard" and in all the more advanced projects discussed in "The Making of a Moon." If, in all this, they are faced with continuing peaceful competition from the U.S.S.R., then at least we may reflect that there are much worse forms which Russo-American competition might take.—A. V. CLEAVER.

ENGINEERING THERMODYNAMICS. *Mackey, Barnard and Ellenwood. Chapman and Hall, London, 1957. 428 pp. Illustrated. 64s.*

Although based on an earlier book by Barnard and Ellenwood, this book is written entirely by their pupil Mackay. He sets out to deal, in some detail, with the principles and applications of engineering thermodynamics declaring that the student "will learn these principles more thoroughly when motivated by his interest in the applications."

After a brief historical survey the first six chapters deal in some detail with the first and second laws of thermodynamics, and their consequences, and with the properties of ideal and real gases. For the student having mathematical inclinations these chapters will form a sound background for later work, although the application of the principles to practical problems is not emphasised to the degree that might have been expected from the preface. After chapters on mixtures of ideal gases and on gas reactions, gas compression is considered from both the theoretical and practical point of view.

The treatment of internal combustion engines is almost entirely theoretical and there is little reference to practical departures from the various standard cycles.

The same might be said of the section on vapour power cycles were it not preceded by a sound theoretical and descriptive chapter on energy transformation in turbines. An otherwise valuable discussion of the properties of vapours is marred by the description of the "Universal Calorimeter" for determination of dryness. As described, and indeed as illustrated, it is hard to see how this instrument could possibly work.

Vapour compression refrigeration cycles are considered in some detail, though the reasons for employing cycles of varying complications are not made clear. Vapour absorption systems are dismissed briefly, as also is air conditioning.

There is no attempt to deal with heat transfer in this volume.

It would appear that the author's main interests are in the theoretical rather than in the practical aspects of his subject. In consequence the theoretical chapters of his book are more satisfying than those dealing partly with practical matters.—H. BILLETT.

PROCEEDINGS OF THE JOINT CONFERENCE ON COMBUSTION. *Institution of Mechanical Engineers, London, 1957. 456 pp. Illustrated. 63s.*

This volume reports on the conferences on Combustion held in Boston, Mass., and London in 1955, and will justly find its way to most technical libraries.

In addition to reports on discussions, some forty-three papers are presented. These are divided into five sections: General, Boilers, Industrial Furnaces, Internal Combustion Engines and Gas Turbines.

Perhaps the most remarkable feature of Section I is the statement by Sherman and Reid that designers have been able to make little use of the results of fundamental combustion research—a challenging statement which went almost uncontradicted at that stage.

In Section II the use of solid, liquid and gaseous fuels in boiler furnaces is considered, but Fraser's paper on "Liquid-fuel Firing" is of general interest outside this field. This is also true of the papers on instrumentation presented in the section on "Industrial Furnaces," which also contains interesting remarks on the uses of models in combustion research.

Internal Combustion Engines in the context of Section IV is restricted to reciprocating engines. This section contains a most interesting range of papers, in particular those on combustion in the dual-fuel engine (Moore and Mitchell) and on an analysis of combustion processes by statistical pressure recording (Vichnievsky).

The section on Gas Turbines contains eleven papers and it is probably these which will be of most direct interest to readers of this Journal. Karlovitz has continued his development of electronic probes for measurements in turbulent flames and his latest instrument is described here. Droms and Dahl discuss the use of Iridium-Iridium-Rhodium thermocouples for high temperature measurements and describe several practical probes. "Heat release rate in hydrocarbon combustion" summarises the results of experimental work in spherical reactors and gives adequate reference to more complete papers. In addition to several papers on combustion in industrial type gas turbines there are papers on the relation between heat

release and pressure drop and on temperature control in aero-gas-turbine combustion chambers.

Probert's final paper to the conference, which summarises some of the combustion research at N.G.T.E., might be described as the reply to Sherman's challenge to those engaged on combustion research. It is perhaps not surprising that this reply should appear in the section on the gas turbine, which must surely owe more to research than any other form of engine.—H. BILLETT.

POSTWAR INTERNATIONAL CIVIL AVIATION POLICY AND THE LAW OF THE AIR. *H. A. Wassenbergh. Martinus Nijhof The Hague. 180 pp. 23s.*

Once again, it is left to the enterprise of the Dutch to produce the best survey in book form of the post-war decade of air transport law and politics. The book is divided into two quite separate but inter-related parts.

Part One deals with international civil aviation policy from 1944 onwards, and traces in a comprehensive fashion the decay of the multilateral traffic hopes of Chicago, the astonishing growth of bilateral agreements, and the mocking nomenclature of the so-called "freedoms" of the air which have caused some of the hardest bargaining in peaceful international diplomacy. Mention is made of the rise of regional attempts at solving particular problems such as the European Civil Aviation Conference.

For Part One alone, the book is a "must" for those whose work and future is bound up with international commercial aviation.

Part Two deals with developments and trends in Air Law relating to traffic rights. Brief consideration is given to the question of airspace sovereignty. Finally some suggestions are made for the encouragement of a new spirit of true internationalism in air transport thinking. This comes well from our friends in Holland who are the world's leading exponents of enterprising internationalism in the best sense.

Footnotes in the book have grown to the dimensions of a miniature parallel treatise. In a scholarly review footnotes are essential—but solely as a source of references. No doubt they arise from the scrupulous intellectual honesty of the author who wishes to give his readers a chance to draw their own conclusions. But the conscientious reader is continually hypnotised away from the text to read massive notes at the foot of the page. Like Buridan's Ass this indecision leads to non-digestion.—H. CAPLAN.

Additions to the Library

Advanced Dynamics. John E. Younger. Ronald Press, New York. 1958. 285 pp. Diagrams. $8.50. A fundamental text-book for graduate engineering students. The chapters cover kinematical analysis; dynamic specification of a rigid body; basic principles; rectilinear, angular and plane motion; motion in three dimensions; dynamics of beams. Well presented and illustrated, with examples at the end of each chapter.

Aircraft Communications Systems. J. H. H. Grover. Heywood and Co., London. 1958. 126 pp. Illustrated. 22s. 6d. *To be reviewed.*

Analytical Design of Linear Feedback Controls. G. E. Newton, *et al.* Chapman and Hall, London. 1957. 418 pp. Illustrated. 96s. *To be reviewed.*

Training Center for Experimental Aerodynamics. Brussels, T.C.E.A. Publication No. 5802. 1957. 14 pp. Descriptive Pamphlet.

Essais en Vol. N. Duke, *et al.* Bibliotheque le livre Contemporain. 1958. 303 pp. Illustrated. 28s. (In French.) With the title "Flight Testing from the Sound Barrier to the Heat Barrier," this is a collection of the reminiscences of famous test pilots of today. The text has been taken from three books: "Test Pilot" by Neville Duke and Alan W. Mitchell, "Ils ont Reconquis Notre Ciel" by Paul Boudier and Marcel Jullian, and "The Lonely Sky" by William Bridgeman and Jacqueline Hazard.

Fluid-dynamic Drag. S. F. Hoerner. New Jersey. 1958. 400 pp. 15 dols. *To be reviewed.*

Geometry of Einstein's Unified Field Theory. Vaclav Hlavaty. P. Noordhoff Ltd., Groningen. 1958. 340 pp. 9 dols.

Hydro-aerodinamica Lubrificatiel. N. Tipei. Editura Academie R.P.R. Bucharest. 1957. 695 pp. Diagrams. (In Rumanian.) A comprehensive treatise, largely mathematical, on the hydro-aerodynamics of lubrication. Based on the author's own researches, the book contains chapters on friction of solids and fluids, viscous fluid motion, lubricants, bearings, stability of motion of lubricated bodies, hydrodynamic lubrication and gas lubrication.

Into Thin Air. E. W. Still. Normalair Ltd., Yeovil. 1957. 215 pp. Illustrated. 18s. 6d. *To be reviewed.*

Jahrbuch der Luftfahrt. K. F. Reuss. Sudwestdeutsvhe Verlagsanstalt, GMBH, Mannheim. 1957. 530 pp. 26s. The standard handbook of matters aeronautical in Germany is now in its sixth year. As Germany's industry and transport side grow so does its year book assume greater value and importance.

Landing Gear Design. H. G. Conway. Chapman and Hall, London. 1958. 342 pp. Illustrated. 56s. *To be reviewed.*

Le Statut Juridique de l'Aeronef Militaire. Peng Ming-Min. Martinus Nijhoff. The Hague. 1957. 114 pp. (In U.K., Batsford, 23s.) An important and well-documented study (in French) of the Legal Status of Military Aircraft in international law, from the end of the nineteenth century to the present day.

Plastics Progress 1957. Papers and Discussions at the British Plastics Convention 1957. Edited by Philip Morgan. Iliffe, London. 1958. 394 pp. Illustrated. 50s. The full length versions, with discussions, of papers presented in an abbreviated form at the 1957 International Plastics Convention held in London. The papers represent some of the most recent international advances in plastics technology, particularly in the fields of polythenes, vinyls, polystyrenes, reinforced plastics and fluorine polymers. Other papers deal with current developments in the theory and practice of extrusion and injection moulding. The authors are leading authorities from the United Kingdom, the United States and Germany.

Properties of Wrought and Cast Aluminium and Magnesium Alloys, at Room and Elevated Temperatures. P. H. Frith. H.M.S.O. for Ministry of Supply. 1956. 178 pp. Illustrated. 22s. 6d. *To be reviewed.*

Report of Conferences on Standardization of Screw Threads and Cylindrical Fits. Combined Production and Resources Board, London. 1944.

Russian Aircraft. John W. R. Taylor. Ian Allen, London. 1958. 32 pp. Illustrated. 2s. 6d. This follows the usual pattern of the A.B.C. books prepared by John Taylor, although the size is a little larger than previous issues. Both military (as far as possible) and civil types are in the same booklet.

I.A.S. PREPRINTS

764 Incompressible two-dimensional stagnation-point flow of an electrically conducting viscous fluid in the presence of a magnetic field. J. L. Neuringer and W. McIlroy.
765 A simple method of matric structural analysis—Part III. Flexible frame and stiffened cylindrical shell analysis. B. Klein.
766 On vibrations of conical shells. G. Herrmann and I. Mirsky.
767 An optimum design for a semi-infinite rocket wall containing a circumferential keyway. B. W. Shaffer *et al.*
768 Supersonic airfoil performance with small heat addition. A. Mager.
769 Vibrations of thin cylindrical shells analyzed by means of Donnell-type equations. Yi-Yuan Yu.
770 Autorotation of fuselages. M. H. Clarkson.
771 Statics and dynamics of non-uniform curved beams and prismatic shells. F. F. Ehrich and J. P. Vries.
772 Transport airplane crash loads. G. M. Preston and G. J. Pesman.
773 The minimum weight of a structure protected against short duration aerodynamic heating by means of thermal insulation. R. A. Dobbins.
774 The Hecker method of transient temperature calculation. A. W. Trimpi.
775 Approximate three-dimensional solutions for transient temperature distribution in shells of revolution. M. A. Brull and J. R. Vinson.
776 Theoretical considerations of flutter at high Mach numbers. H. G. Morgan *et al.*
777 Thermal stresses and deflections in rectangular sandwich plates. P. P. Bijlaard.
778 Some effects of curvature on frames. R. W. Westrup and P. Silver.
779 Creep and static strengths of large bolted joints of forged aluminum alloys under various temperature conditions. L. Mordfin *et al.*
780 Aircraft fatigue—is low strength material the answer? C. R. Smith.
781 Hydro fatigue test of the C-130A Hercules. J. E. York.
782 On optimum thin lifting surfaces at supersonic speeds. H. Yoshihara *et al.*
783 A semi-empirical analytical method of obtaining aerodynamic derivatives. N. H. Van Dorn.
784 A comparison of theoretical and experimental loads on the B-47 resulting from discrete vertical gusts. C. E. Jackson and J. E. Wherry.
785 Some structural response characteristics of a large flexible swept-wing airplane in rough air. T. L. Coleman *et al.*
786 A rational determination of loads and exit velocities of cartridge ejected stores. H. Wolf and S. Pines.
787 Some applications of theoretical aerodynamics to the design of high performance aircraft. G. C. Grogan.
788 Aeroballistics range measurements of the performance and stability of supersonic aircraft. H. R. Warren *et al.*
789 The minimum wave-drag problem for the addition of a body to a given airplane configuration. J. F. Vandrey.
790 Air traffic demand of the decade: 1953-1963. A. D. Harvey.
791 The jet-flapped wing in two- and three-dimensional flow. W. F. Jacobs and J. H. Paterson.
792 The transonic flow field of an axial compressor blade row. J. E. McCune.
793 A linear perturbation method for stability and flutter calculations on hypersonic bodies. M. Holt.
794 The satellite tracking camera. J. Nunn.
795 The air force instrument development program. M. C. Demler.
796 The environment of space in human flight. C. A. Berry.
797 Supersonic and hypersonic human flight. J. E. Ward *et al.*
798 Cybernetics in human flight. G. T. Hauty.
799 The development of the air route structure and separation standards. L. E. Warren.
800 The role of radar in air traffic control 1953-1963. J. H. Hilton.
801 The supersonic blunt-body problem—Review and extension. M. D. Van Dyke.
802 Chemical relaxation in air, oxygen and nitrogen. M. Camac *et al.*
803 Intelligence sources for guidance. A. S. Locke.
804 The development of the Talos land-based system. D. B. Holmes.
805 Pitch-lag instability of helicopter rotors. Pei Chi Chou.
806 Direct analog method of analysis of the vertical flight dynamic characteristics of the lifting rotor with floating hub. R. H. MacNeal.
807 Pitch-lag instability as encountered during tests of a model rotor. J. W. McFee.
808 Research in the field of wingless VTOL aircraft. A. M. Lippisch.
809 Naval applications of VTOL-STOL vehicles. H. G. Sheridan.
810 Solutions for helicopter rotor blade icing. D. A. Richardson *et al.*
811 An analytical procedure for the preliminary structural and dynamic design and weight estimation of helicopter rotor blades. A. Rasumoff.
812 On the hydrodynamic stability of curved laminar compressible flows. M. Lessen.
813 Long-range planning (A symposium). W. B. O'Neal *et al.*
814 NACA research in the field of VTOL and STOL aircraft. C. H. Zimmerman.
815 The Army-Navy instrumentation program. G. W. Hoover.
816 On reducing aerodynamic heat transfer rates by magnetohydrodynamic techniques. R. C. Meyer.
817 Examples of detached bow shock waves in hypersonic flow. P. R. Garabedian and H. M. Lieberstein.
818 The dynamics and certain aspects of control of a body re-entering the atmosphere at high speed. J. D. Welch and S. L. Shih.
819 Interrelations of space medicine with other fields of science. H. Strughold.
820 Analysis of the vertical flight dynamic characteristics of the lifting rotor with floating hub and off-set coning hinges. K. H. Hohenemser and C. H. Perisho.
821 Development, flight test and evaluation of a mechanical stabilizer for single rotor helicopters. G. E. Dausman *et al.*
822 Effects of a time-varying test environment on the evaluation of dynamic stability with application to flutter testing. W. H. Reed.
823 The plastic balloon as a geophysical platform. R. H. Braun.
824 Project Far Side launchings. J. L. Cramer.
825 Industry and education (combining 3 of the 4 papers presented). C. S. Draper *et al.*
826 Supersonic civil air transport with consideration of potential VTOL capabilities. J. A. O'Malley.
827 Preliminary investigation of a ducted fan in lifting forward flight. N. D. Ham and H. H. Moser.
828 Booster propulsion for space vehicles. R. S. Wentink.
829 The regulatory problems of jet aircraft. O. Bakke.
830 Cosmology. W. H. Bostick.
831 The Arctic distant warning system. W. E. Burke.
832 The flying platform as a research vehicle for ducted propellers. A. H. Sacks.
833 The three manned stratosphere balloon ascents of 1957. O. C. Winzen.
834 The role of manned balloons in the exploration of space. M. D. Ross and M. L. Lewis.

Reports

AERODYNAMICS

BOUNDARY LAYER—*see also* THERMO-AERODYNAMICS
INTERNAL FLOW

Laminar boundary layer with heat transfer on a cone at angle of attack in a supersonic stream. E. Reshotko. N.A.C.A. T.N. 4152. *December* 1957.

The equations of the compressible laminar boundary layer for the windward streamline in the plane of symmetry of a cone at angle of attack are presented and solved.—(1.1.1.4 × 1.9.1).

Approximate calculation of the compressible turbulent boundary layer with heat transfer and arbitrary pressure gradient. E. Reshotko and M. Tucker. N.A.C.A. T.N. 4154. *December* 1957.—(1.1.3.4 × 1.9.1).

COMPRESSIBLE FLOW—*see also* THERMO-AERODYNAMICS
WINGS AND AEROFOILS
TESTING AND INSTRUMENTS

Some proposals regarding the definitions of terms relating to various flow régimes of a Gas. C. H. E. Warren and A. D. Young. C.P. No. 368. 1958.—(1.2).

Experiments at $M = 1{\cdot}41$ on elliptic cones with subsonic leading edges. E. W. E. Rogers and C. J. Berry. R. & M. 3042. 1957.

Tests have been made at a Mach number of 1·41 on six elliptic cones forming two families of models. In the first the vertex angle in the plane of the major axis of the elliptic cross-sections was maintained constant at 60° and the ratio between the minor and major axes varied; in the second family the minor axis was constant and the vertex angle had values of 30°, 60° and 90°. Two cones from the first family were pressure plotted at incidences up to 15°, the resulting pressure distributions being integrated to give lift and pressure drag arising from the curved surfaces of the cones. Except for one of the pressure plotting models, lift, drag and centre of pressure position were measured for all models on a strain gauge balance.—(1.2.3).

Turbulence measurements in multiple interfering air jets. J. C. Laurence and J. M. Benninghoff. N.A.C.A. T.N. 4029. *December* 1957.

Turbulent and mean-flow characteristics of several noise-suppression multiple-jet nozzles have been determined from hot-wire anemometer measurements for flow conditions at a Mach number at 0·3 and Reynolds number of $2{\cdot}06 \times 10^6$ per ft.—(1.2.1).

*Transmission of electromagnetic waves through ionized air surrounding hypersonic aircraft. Z. O. Bleviss. Douglas Report No. SM-*22965. *October* 1957.

Transmission through two different regions on a hypersonic aircraft are studied: (1) the blunt nose region and (2) the high-speed laminar or turbulent boundary layer on a slender afterbody. Assuming thermodynamic equilibrium and using well-known equations for the propagation of electromagnetic waves in the ionosphere, two effects are studied: (1) the attenuation of the waves as they pass through the ionised air, and (2) the reflection of the waves as they impinge on the ionised air from a homogeneous region of non-ionised air. These effects are studied as functions of speed, altitude and wave length. In a discussion of the very important assumption of thermodynamic equilibrium it is pointed out that the results based on this assumption probably correspond to the worst possible situation with regard to the transmission of electromagnetic waves. In actual cases the non-zero ionisation relaxation times always relieve the situation.—(1.2.3.1 × 32.2.1).

FLUID DYNAMICS

Vortex tube performance data sheets. R. Westley. CoA Note No. 67. *July* 1957.

These data sheets are intended as an aid to the estimation of the performance of vortex tubes with given characteristics. In particular, the present note provides the optimum values of the vortex tube parameters which give maximum temperature drops.—(1.4.3 × 1.5.1).

*Three dimensional motions in closed regions at large Reynolds numbers. W. W. Wood. A.R.L. Report A.*106. *November* 1957.—(1.4).

INTERNAL FLOW—*see also* FLUID DYNAMICS
POWER PLANTS

Experimental and theoretical investigations of the flow of air through two single-stage compressors. J. H. Horlock. R and M. No. 3031. 1957.—(1.5.2.1).

Velocity and friction characteristics of laminar viscous boundary layer and channel flow over surfaces with ejection or suction. E. R. G. Eckert et al. N.A.C.A. T.N. 4102. *December* 1957.

Dimensionless flow parameters common to both channel and boundary layer flow were developed in order to determine the extent to which the boundary conditions imposed on the flow by the various geometries influence the flow characteristics.—(1.5.1.1 × 1.1.1).

LOADS

Analysis of horizontal-tail loads in pitching manoeuvers on a flexible swept-wing jet bomber. W. S. Aiken. N.A.C.A. T.N. 4191. *December* 1957.

Horizontal-tail loads measured by means of strain gauges in pitching manoeuvres are analysed to determine wing-fuselage aerodynamic centre position, zero-lift pitching-moment coefficients, aeroplane pitching moment of inertia, and radius of gyration.—(1.6.2 × 1.8.2.1 × 2 × 13.2).

Measurement of aerodynamic forces for various mean angles of attack on an airfoil oscillating in pitch and on two finite-span wings oscillating in bending with emphasis on damping in the stall. A. G. Rainey. N.A.C.A. Report 1305. 1957.

The oscillating air forces on a two-dimensional wing oscillating in pitch about the midchord have been measured at various angles of attack and at Mach numbers of 0·35 and 0·7.—(1.6.3 × 2).

A study of the correlation between flight and wind tunnel buffet loads. W. B. Huston. AGARD Report 111. *April-May* 1957.

The power spectrum and probability distribution of the buffet loads as measured by electrical wire resistance strain gauges suggest that these loads can be considered as the linear response of a lightly damped single-degree-of-freedom system to a random input. Dimensional analysis and beam theory are employed to develop a relation between the buffet loads on an aeroplane in flight and the loads on a model in a wind tunnel. Flight and model results are compared for several different configurations.—(1.6.3 × 33.1.2).

STABILITY AND CONTROL—*see also* LOADS
MISSILES

A method of optimising aircraft autostabilizer systems. J. Wolkovitch. CoA Report No. 113. *May* 1957.

Although the presence of the pilot is explicity taken into account in the calculations no form of pilot's transfer function need be specified. It is shown how the procedure may be modified to form an approximate procedure for the optimisation of autostabilisers for pilotless aircraft having linear autostabiliser characteristics and linear aircraft dynamics. The results of some calculations presented support a suggestion that this approximate optimisation procedure may also be frequently applied with success to pilotless aircraft having certain non-linearities, either in the autostabiliser system or in the aircraft dynamics.—(1.8 × 25).

NOTE.—*The figures in parenthesis at the end of each Summary are for office use only.*

Transition-flight investigation of a four-engine-transport vertical-take-off airplane model utilizing a large flap and extensible vanes for redirecting the propeller slipstream. L. P. Tosti. N.A.C.A. T.N. 4131. *December* 1957.

An investigation of the stability and control of a four-engine vertical take-off transport aeroplane during the transition from hovering to normal forward flight has been conducted with a remotely controlled free-flight model. The model had a 65 per cent-chord flap which was deflected 85° in hovering flight, eight extensible vanes arranged above the wing in a cascade relation, and four propellers located along the wing with the thrust axes essentially parallel to the fuselage axis.—(1.8.2 × 1.12.2)

THERMO-AERODYNAMICS—*see also* BOUNDARY LAYER

Formulae and approximations for aerodynamic heating rates in high speed flight. R. J. Monaghan. C.P. 360. 1957.

Formulae and approximations suitable for making preliminary estimates of aerodynamic heating rates in high speed flight are given. The formulae are based on the "intermediate enthalpy" approximation which has given good agreement with theoretical and experimental evidence. In the general flight case they could be used in conjunction with an analogue computer or a step-by-step method of integration to predict the variations of heat flow and skin temperature with time. In the restricted case of flight at constant altitude and Mach number, simple analytical methods and results are given which include the effects of radiation and can be applied to "thick" as well as "thin" skins.—(1.9).

Heat transfer and recovery temperatures on a sphere with laminar, transitional, and turbulent boundary layers at Mach numbers of 2·00 *and* 4·15. *I. E. Beckwith and J. J. Gallagher. N.A.C.A. T.N.* 4125. *December* 1957.

An investigation was made of the pressure, equilibrium temperatures, and aerodynamic heat transfer on a sphere and on the nose of a hemisphere cylinder.—(1.9.1 × 1.2.3 × 1.1).

WINGS AND AEROFOILS

The harmonically oscillating wing with finite vortex trail. P. F. Jordan. R. and M. No. 3038. 1957.

The wing of infinite span oscillating harmonically in incompressible flow but having a vortex trail of finite length Sc is discussed theoretically. The "incomplete circulation function" C_s which arises in this case is tabulated. As an example, the damping moment due to slow pitching oscillations is shown for several values of S. The result is of interest as a wind tunnel correction, in particular in that range of small frequencies which occurs in flight stability oscillations.—(1.10.1.1).

*Curves of minimum wave plus vortex drag coefficient for several wing planforms. B. J. Beane. Douglas Report No. SM-*22989.

Curves have been prepared showing the minimum drag coefficient values which may be theoretically obtained for several different wing plan forms at Mach numbers of 2, 3, and 4. The values presented represent the wave plus vortex drag, as computed by linearised theory, for wings that are twisted and cambered such that the surface loading is optimum; that is the $C_{D\ \text{wave+vortex}}/C_L{}^2$ for this loading is a minimum.—(1.10.1.2 × 1.2.3.2).

HELICOPTER AERODYNAMICS

The effect of the ground on a helicopter rotor in forward flight. I. C. Cheeseman and W. E. Bennett. R. & M. No. 3021. 1957.

An approximate method of estimating the effect of the ground on the lift of a rotor at any forward speed is described. Flight tests on several different helicopters show reasonable agreement with the theory. Curves are given showing the relation between thrust, height, speed and power. The theory has been extended to include the effect of a variation in blade loading coefficient. The effect of fitting flat surfaces beneath the rotor is also considered.—(1.11.3).

TESTING AND INSTRUMENTS—*see also* STABILITY AND CONTROL
DESIGN AND CONSTRUCTION
SCIENCE-GENERAL

Nozzle and contraction shapes of the R.A.E. 3 *ft.* × 3 *ft. supersonic wind tunnel. A. Stanbrook. C.P.* 375. 1957.

Ordinates of the contraction and of each of the solid liners of the 3 ft. × 3 ft. supersonic wind tunnel are tabulated.—(1.12.1.3).

The design, instrumentation and operation of the UTIA low density wind tunnel. K. R. Enkenhus. U.T.I.A. Report No. 44. *June* 1957.

The UTIA low density wind tunnel is a continuous open circuit tunnel with vacuum pump drive designed to operate at Mach numbers up to 5 over a range of low pressures suitable for the study of rarefied gas flows. Booster-type oil diffusion pumps are used to provide a range of operating pressures from 0·001 to 0·070 mm. Hg. The Reynolds number per inch varies from 0·1 to 4×10^3. The design, construction, instrumentation and operation of the tunnel, nozzle calibration, and low density effects on pressure probes are discussed. A theoretical study is made of conventional axisymmetric nozzles and slotted wall nozzles with boundary layer suction. Calibrations are given for $M = 4$, $M = 2$, and subsonic flow nozzles operated at static pressures of 0·040, 0·020 and 0·008 mm. respectively.—(1.12.1.3).

The shock tunnel and its applications to hypersonic flight. A. Hertzberg. AGARD Report 144. *July* 1957.

The application of the shock tube to the study of the problems of hypersonic flight is discussed. The development of the shock tube into a short-duration wind tunnel for the study of supersonic air flow is reviewed historically. Modifications of the conventional shock tube which extend the shock tube into a tool for the study of hypersonic flows are described. Finally, the present experimental programme under way at Cornell Aeronautical Laboratory is briefly reviewed, and the results of some recent interesting experiments introduced.—(1.12.1.3).

Physical gas dynamics research at the AVCO Research Laboratory. P. H. Rose. AGARD Report 145. *July* 1957.

A resumé of the first year's work of the AVCO Research Laboratory on high temperature gas dynamics. The advantages of the straight shock tube for investigation in this field are discussed. Several investigations conducted in shock tubes, into critical gas dynamic problems associated with the high temperatures of flight at hypersonic Mach numbers are described and preliminary studies of magneto-hydrodynamics are summarised.—(1.12.1.3 × 1.2.3).

Instrumentation and data handling methods for determining load distribution on wind tunnel models by pressure distribution measurements. J. P. Doyle. AGARD Report 114. *April-May* 1957.

Two types of instrumentation are described.—(1.12.6).

AEROELASTICITY

See also AERODYNAMICS—LOADS

Flutter prediction in practice. E. G. Broadbent. C.P. No. 373. 1957.

A brief summary is given of the resources available for flutter prediction, both experimental and theoretical. Specific flutter investigations are described for four separate flutter incidents which have occurred in Great Britain during the past few years. Conclusions for future guidance are drawn from all the examples, with particular reference to the aerodynamic treatment. The paper concludes with a few points from a more general statistical survey of recent incidents.—(2).

Response of elastic aircraft to continuous turbulence. R. L. Bisplinghoff et al. AGARD Report 117. *April-May* 1957.

A review is made of a method for determining the disturbed motion and the corresponding stresses of an elastic aircraft. The method is applied to the solution of the response of aircraft to continuous turbulence. Results are presented of the stress amplification due to flexibility of the structures. Discussions include effects of the scale of turbulence and of the spanwise variations of gust intensity on the responses and stresses of flexible aircraft.—(2×33.2.3.0).

DESIGN AND CONSTRUCTION

Wind tunnel tests on seaplane hulls in the R.A.E. 5 ft. diameter open jet tunnel and the N.P.L. compressed air tunnel. A. G. Smith. R. & M. No. 3018. 1957.

Results of research work done in this country and the subject matter of Refs. 1 to 4 on the measurement and analysis of the air drag of seaplane hulls are collected together in this report. The tests were conducted to find out the origin and order of the component drags of a hull and to determine in what way the hull drag differed from that of an equivalent body of revolution. Tests were made over Reynolds numbers ranging from the order of 2 to 60 $\times 10^6$ in order to examine the scale effect as far as possible, and a few tests were made to determine the possible effect of controlling boundary-layer-transition. Otherwise all tests were made transition free. Subsequent to the systematic tests, tests were made on a specific hull form to investigate the form of step fairing designed for the Princess flying boat, which form may be regarded as the best so far applied to hulls of contemporary fineness ratio and beam loading.—(4.5.2.2×1.12.1.1).

FLIGHT TESTING

See also AERODYNAMICS—LOADS

Measuring climb performance of a propeller engined transport aeroplane using the accelerometer technique. J. P. K. Vleghert. AGARD Report 127. *May* 1957.

Some possibilities of the accelerometer technique are given, together with a discussion of some problems in instrumentation, especially measuring angle of attack and longitudinal acceleration. With the accelerometer technique it is feasible to analyse the total aeroplane drag into its components, *i.e.* basic drag with propellers feathered, propeller slipstream drag and extra drag in one engine out flight due to side slip and control deflection. Some obtainable accuracies are quoted.—(13.3).

INSTRUMENTS AND EQUIPMENT

High speed computers in the aircraft industry. F. P. Cozzone. AGARD Report 130. *May* 1957.

The phenomenal growth of the use of high speed digital computers for solving typical problems associated with the aircraft industry is discussed. A capability comparison is made between the progressive computers utilised to date and this comparison is extrapolated to computers that will be available in the next few years. The variety of problems capable of being solved in a practical manner is also discussed, with pertinent comments as to the future role of the engineer.—(18).

MATERIALS

See also FATIGUE

Selected properties of structural materials at elevated temperatures. D. A. Shinn. AGARD Report 104. *April* 1957.

In addition to the normally determined elevated temperature tensile properties, and creep and fatigue tests under constant conditions, the aircraft or missile airframe designer also needs such materials information as effect of time at temperature, loading rate, sequence of temperature or load application, state of stress, other properties as affected by temperature, such as compression, bearing, shear and physical constants. Properties selected from this group are presented in summary or as progress reports on current U.S.A. work. References to more complete information are also provided. Materials which are considered are aluminium, magnesium, titanium, steel and special high temperature alloys.—(21.2.2).

*The production of high purity chromium from fluoride containing electrolytes. N. E. Ryan. A.R.L. Report Met.*26. *October* 1957.

A description is given of the production of high purity electrolytic chromium from a high-efficiency chromic acid-fluoride electrolyte.—(21.2.2).

*The ageing characteristics of two commercial alloys based on the aluminium-zinc-magnesium system. I. J. Polmear and P. Scott-Young. A.R.L. Report Met.*25. *October* 1957.

A study has been made of the ageing characteristics of the commercial alloys 75S and DTD.687. Hardness-ageing time curves were determined in the temperature range −20° to 200°C and the results were compared with the curves which were obtained for a pure ternary alloy with similar zinc and magnesium contents. The effect of cold work prior to ageing the commercial alloys was also studied. The main object of the investigation was to obtain information concerning the roles of copper, chromium and magnesium in the ageing processes of the commercial alloys.—(21.2.2).

The strength of annealed and heat-treated glass. F. G. J. Brown and J. Ellis. R. & M. No. 3003. 1957.

Statistical methods of choosing allowable design stresses for annealed and heat-treated glass are developed. The influence of the known causes of strength variations between nominally identical specimens in relation to two types of glass typical of those used by the aircraft industry are discussed, and that improved control of heat-treatment processes offers the best hope of a big increase in the useful strength of glass is shown.—(21.3.3).

MISSILES

See also AERODYNAMICS—STABILITY AND CONTROL

Three-degree-of-freedom evaluation of the longitudinal transfer functions of a supersonic canard missile configuration including changes in forward speed. E. C. Seaberg. N.A.C.A. T.N. 4192. *December* 1957.—(25×1.8.2.1).

Measurements of the paths of the vortex cores shed from the wings of a typical guided-missile model at $M=1{\cdot}57$. *R. H. Plascott. R. & M. No.* 3016. 1957.

The paths of the cores of the vortex sheets shed from the wings of a typical guided missile model, having cruciform rectangular wings mounted on a long cone-cylinder body, have been traced in their movement downstream over a range of incidence and yaw from 5° to 20° and 0° to 20° respectively at $M=1{\cdot}57$.—(25.2).

POWER PLANTS

Propulsion supersonique par reacteurs. M. Roy. O.N.E.R.A. Tech. Note No. 42. 1957. (*In French*).

Supersonic jet engines using ambient air are studied by establishing and analysing the applicable fundamental formulae. The overall characteristics of the power plants together with the effects of air intakes, combustion chambers and exit nozzles are examined. The turbo-jet with or without reheat, the ram-jet, and combinations of both types of engine are examined with reference to the particular flight régime for which each is most suited.—(27.1×27.4).

A method of performance estimation for axial-flow turbines. D. G. Ainley and G. C. R. Mathieson. R. & M. No. 2974. 1957.

A method for calculation of the performance of conventional axial-flow turbines is presented. It makes use of data derived from the analysis of a large number of turbine tests and to other associated test work reported elsewhere. The method enables the performance of a turbine to be calculated over a wide part of its full operating range. It is estimated that the tolerance on the absolute values of gas mass flow and peak efficiency will be in the region of ± 2 per cent for efficiency and ± 3 per cent for gas mass flow on present day types of turbine. This method is illustrated by a worked example.—(27.1.1×1.5.3.1).

La influencia de la presión y temperatura del aire en el decolaje de aviones con varias clases de propulsión. R. Schmidt. Aero Argentina. Comunicaciones e informes 1-5. (*In Spanish.*)

Some formulae derived for the calculation of the influence of ambient pressure and temperature variations upon the static thrust of several kinds of aero-engines are dealt with. Piston-engines with and without manifold pressure and r.p.m. regulators, jet-engines with and without after-burner, and turbo-props are considered. The introduction of the results into the conversion formulae derived by Gothert-Ribnitz permits an easy calculation of the effect of pressure or temperature variations upon the length of the take-off run of modern aeroplanes.—(27).

PROPELLERS

Aerodynamic characteristics at high speeds of related full-scale propellers having different blade-section cambers. J. D. Maynard and L. B. Salters. N.A.C.A. Report 1309. 1957.

Comparisons are made of results obtained in wind-tunnel tests of related full-scale propellers over a range of blade angles from 20° to 55° at air speeds up to 500 m.p.h. to evaluate the combined effects of blade-section camber and compressibility on propeller aerodynamic characteristics. —(29.1).

FATIGUE

The behaviour of cold-worked copper in fatigue. D. S. Kemsley. ARL/Rep./MET 23. *July* 1957.

Results are presented in which specimens of annealed and cold-worked copper, prepared from the same batch of material, were tested to fracture under alternating stresses and examined by X-ray diffraction, optical and electron microscopy, and hardness tests. Subsequently, specimens were annealed at constant heating rate and examined periodically during heating to 900°C.—(31.2.2.5 × 21.2.2).

Fatigue investigation of full-scale transport-airplane wings. Variable-amplitude tests with a gust-loads spectrum. R. E. Whaley. N.A.C.A. T.N. 4132. *November* 1957.

Crack-initiation areas, frequency of occurrence of cracks, crack propagation, lifetime to crack initiation of all cracks, lifetime to final failure, and spread in lifetime are investigated and compared with results from constant-amplitude tests on similar wings. Information on X-ray techniques to determine the presence of cracks in hidden elements is also included.—(31.2.4.2).

The effect of pickling and anodising on the fatigue properties of 2L40 and DTD683 aluminium alloys. J. M. Finney. ARL/Rep/SM 255. *July* 1957.

Results are presented of unnotched rotating cantilever fatigue tests on the aluminium alloys 2L40 (now L56) and DTD.683 to determine the effects of pickling and anodising on the fatigue properties.—(31.2.2.3.1.5).

SCIENCE—GENERAL

See also AERODYNAMICS—COMPRESSIBLE FLOW

Les méthodes scientifiques dans les techniques modernes: quelques écueils. P. Vernotte. Pubs. Sc. et Tech. No. N.T. 70. 1957. (*In French*)—(32).

*Application of multiple-source Schlieren systems. E. Behun. ASTIA AD-*115408. *November* 1957.

Analytical and experimental results are given of an investigation of three applications of the multiple-source Schlieren technique. Consideration was given to (1) large perforated-wall transonic wind tunnels requiring mirror optics (2) colour rendition of flow disturbances in perforated-wall transonic tunnels, and (3) exploitation of the sharp-focusing property of the multiple-source Schlieren system for application to wind tunnels having transparent side walls. —(32.2.4 × 1.12.1.2).

STRUCTURES

LOADS—*see* AERODYNAMICS—LOADS

THEORY AND ANAYLSIS—*see also* AEROELASTICITY

Determination of the stress distribution in reinforced monocoque structures. Part II. A theory of swept wings where the ribs are in the line of flight. L. S. D. Morley. R. & M. No. 2967. 1957.

A method of estimating the stresses caused by root constraint in a two-spar swept wing of reinforced monocoque construction where the ribs are parallel to the line of flight is given. A wing loading condition is also derived which produces zero rib warping, *i.e.* there is no redistribution of stress at the root of the wing. Tests on a cellulose-nitrate model have provided good qualitative confirmation of the theory.—(33.2.3.2).

*Static strength tests on B/2 "Jindivik" rear fuselages of riveted and adhesive bonded construction. R. P. Brown et al. A.R.L. Note SM-*238. *January* 1957.

Static strength tests were conducted on two B/2 "Jindivik" rear fuselages, one of riveted construction and the other of adhesive bonded construction. Both fuselages were loaded to failure for the Lateral Gust 20° Flap case.—(33.2.3.3).

Records of static pressure tests on pressure cabins. P. B. Hovell and A. R. Butler. C.P. 376. 1958.

Results of static pressure tests on 20 fuselages are given. The information is primarily for record and further use as required. Brief details of the locations of premature failures are given, and general conclusions are drawn to account for the difference in the results obtained for fighter and transport aircraft.—(33.2.3.3).

*Normal mode analysis of beams of non-uniform cross-section with tabulated results for some linearly tapered clamped-pinned beams. R. S. Julius and S. Ranta. N.A.E. Report LR-*210. *September* 1957.

A theory is presented for the free lateral vibration of long non-uniform beams in which the space-dependent part, a homogeneous boundary value problem, is written as an integral equation by means of Green's function. Data are presented for a wave form analysis for given beam initial conditions using the first five modes of vibration.—(33.2.4.1.2).

THERMODYNAMICS

Enthalpy charts: for dissociating gas mixtures in the temperature range 600 *deg. to* 4000 *deg. K. H. Reichert. R. & M. No* 3015. 1957.

Enthalpy charts have been constructed to facilitate dealing with the thermodynamic problems of combustion and flow of dissociating gases within the temperature range of 600° to 4,000°K. By means of a quantity called "reaction enthalpy" (which is defined), it is possible without previous knowledge of the composition of the mixture of gases to work out the dissociation processes occurring at equilibrium. Also if required, the composition of the mixture can be obtained from the charts. The charts are confined to the C, H, O, -system, but their extension to include N in the system is quite simple.—(34.1).

Spontaneous-ignition data of hydrocarbons and aviation fluids. E. M. Goodger. CoA Note No. 68. *September* 1957.

The standard A.S.T.M. method has been used to determine comparative spontaneous-ignition characteristics of 29 hydrocarbons and aviation fluids. Reasonable correlation is found with results from more precise methods. Ignition temperature levels are similar in the case of paraffins, olefins, and naphthenes, but are slightly higher with alcohols, and much higher with aromatics. Ignition temperature of petroleum-based aviation fluids show a general reduction with increase in specific gravity.—(34.1.1).

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